Title

Evaluating the role of informal learning in secondary school science teachers' professional development

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Submitted in fulfilment of the requirements of the degree of Doctor of Philosophy

(January, 2021)

Abstract

This study examines the informal learning undertaken by secondary school science teachers, in order to enhance their professionality. Situated within the field of science education, this research focuses on the role of informal learning in science teachers' professional development (PD). While there is a substantial body of research examining teachers' formal PD, there has been limited research on science teachers' informal learning as a form of PD. This study aims to broaden our understanding regarding the ways by which teachers develop their professionality across their career. Specifically, the study posed the following questions: How frequently are secondary school science teachers presently accessing informal learning resources? What are the teachers' purposes in accessing informal learning resources? And how do the number of years teaching experience relate to teachers' usages of the various informal learning resources? A mixed methods approach was applied to the collection and analysis of data from two sources: semi-structured questionnaires with secondary school science teachers (*n* = 91); and two focus group sessions – one with biology teachers (*n* = 11), and one with chemistry teachers (*n* = 6). Teachers identified the frequency and purposes of accessing 32 resources. The various resources were grouped into the following four categories: *interactive media resources*, *non-interactive media resources*, *interpersonal communications*, and *exhibitory and experiential learning resources*. The findings reveal specific preferences for types of resources, and clear purposes for accessing informal learning. In regard to the preferred resources, teachers prioritise the use of *non-interactive media resources*, such as Google and YouTube, over *interactive media resources* such as Facebook and Twitter; and, resources which provide 'tailored' information, such as Google over resources which provide general, non-specific, information such as newsletters and online courses. The most highly prioritised source of informal learning is *conversations with colleagues*. *Online interactive communications* do not appear to be a substitute for face-to-face contact. No significant differences were found in the frequency with which teachers with a different number of years of science teaching experience, access the various informal learning resources. In regard to the purposes of accessing informal learning, the study reveals two distinguishable needs: the first is

as a means for developing professional identity, and the second purpose is to aid teaching. The discussion of the findings highlights the need for providing and promoting opportunities for face-to-face, peer conversations among teachers, and that these face-to-face conversations cannot be replaced by online alternatives. It further suggests that informal learning contributes not only to enhancing the teachers' science teaching capabilities but also to the lifelong development of their professional identity. This study provides practical implications suggesting that accreditation bodies need to find more accurate indices for capturing the ways in which teachers enhance their professionality. Similarly, principals, and organisers of PD need to develop more awareness regarding the informal PD needs of science teachers and to facilitate these accordingly.

Student Declaration

"I, Fiachra Barry, declare that the PhD thesis entitled 'Evaluating the role of informal learning in secondary school science teachers' professional development is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature 

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List of Abbreviations

ACARA - Australian Curriculum, Assessment and Reporting Authority

ACER - Australian Centre for Education Research

AGQTP - Australian Government Quality Teacher Programme

AP - Advanced Placement

APST - Australian Professional Standards for Teachers

BTN – Biology Teachers Network

CEA - Chemistry Education Association

CK - Content Knowledge

CPD - Continuous Professional Development

DEECD - Department of Education and Early Childhood Development

EC – Education Council

GTAC - Gene Technology Access Centre

ICT – Information and Communication Technology

IM – Instant Messaging

ISEI – Informal Science Education Institutes

IWL – Informal Workplace Learning

LSM - Learning Management System

MOOC – Massive Online Open Course

NARST - National Association of Research in Science Teaching

NAS – National Academy of Science

NMAP - National Mathematical Advisory Panel

NOS – Nature of Science

NSF – National Science Foundation

OECD - Organisation for Economic Co-operation and Development

PCK - Pedagogical Content Knowledge

PD – Professional Development

PGC - Professionally Generated Content

PL – Professional Learning

QTS – Qualified to Teach Status

SCTE - School Centres for Teaching Excellence

SIS - School Innovation in Science

SPSS - Statistical Package for Social Science

STAV - Science Teachers' Association of Victoria

STEM – Science Technology Engineering and Mathematics

TALIS - Teaching and Learning International Survey

TES - formerly known as the Times Educational Supplement

TEMAG - Teacher Education Ministerial Advisory Group

TPACK - Technological Pedagogical and Content Knowledge

TV - Television

UNESCO - United Nations Educational, Scientific and Cultural Organization

UGC - User Generated Content

VCAA - Victorian Curriculum and Assessment Authority

VCE - Victoria Certificate of Education

VIT – Victorian Institute of Teaching

Vicphysics – Victoria Physics Teacher Network

VOIP – Voice-Over Internet Protocol

1. INTRODUCTION

The present study is situated within the field of science education. Within this broad field, the study brings together the two areas of: research into teachers' professional development (PD), and research into informal learning. Particularly, my aim is to investigate the role of science teachers' informal learning in enhancing their PD across their career path. This chapter first presents the background and motivation for the research, followed by the research questions which guide the study, and concludes with an overview of the research process.

The nature of teacher professionalism has been debated over the years (Kennedy, 2007). Hargreaves (2000) has presented the development of teacher professionalism as passing through four historical stages: The pre-professional stage (prior to 1960s); the autonomous stage (1960s to mid-1980s); the collegial stage (late-1980s to 2000); and the post-professional stage (from 2000 onwards). The *pre-professional* stage viewed the teacher as a virtual amateur, merely carrying out the directives of their more knowledgeable superiors. In the *autonomous* stage, teachers had autonomy over curriculum development and were not constrained by the requirements of external examinations. The *collegial* stage was characterised by teachers embracing consultation, collaborative planning and other kinds of joint work with colleagues. In the current *post-professional* stage teachers struggle with centralized curricula, testing regimes and external surveillance, the economic imperatives of marketization (Hargreaves, 2000, p. 153), and corporate style management (Day, 2002). This includes performance cultures which are expressed through increased accountability, and the continued imposition of teacher standards (Sachs, 2016). Teachers in many countries now work within cultures in which their careers are ever more dependent upon external definitions of quality, progress and achievement as indicators of capability and success (Day, 2002). Various scholars perceive this post-professional teacher status as being derived from a deficit model (Meiers & Ingvarson, 2005; Thomas, 2011), where the emphasises on accountability and compliance devalues teachers as autonomous and self-directed learners (Hargreaves & Goodson, 1996). A deficit model of teacher professionalism does not take into account a teacher's

professional identity, and what motivates them as a person and as a teacher (Day, 2002; Guskey, 2003).

Upon the backdrop of increased accountability, participation in PD activities has become a mandatory requirement by many teacher registration bodies, designed to ensure that teachers are keeping up-to-date with changes in curriculum and pedagogy (Scheerens, 2010; Victorian Institute of Teaching [VIT], 2019). This, in turn, promotes the widespread use of organised formal PD activities involving discrete units of knowledge that are delivered to teachers by experts (Kennedy, 2005; Sachs, 2016). Some authors distinguish between teacher professional learning and teacher professional development (Berry et al., 2009; Prestridge et al., 2019). Professional development suggests the supply of pre-packaged knowledge to teachers, compared to professional learning as the sharing of insights about teaching and learning (Berry et al., 2009). While acknowledging these distinctions, in this thesis I will use the term *professional development* as inclusive of both terms. This choice is justified as the Victorian Institute of Teaching (VIT) does not make a distinction between these terms (VIT, 2019).

Studies examining the effectiveness of formal PD activities in enhancing teachers' professionality highlight various limitations. Among them is the finding that many formal PD activities are often geared towards a virtual 'average' teacher and thus, these do not address individual teachers' learning needs (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009). Overall, formal PD activities provide only partial support to teachers in their efforts to meet their professional needs (Guskey et al., 2009).

Research into lifelong learning suggests that the increasing complexities and the rapidly changing nature of today's working environments requires workers to engage in ongoing learning (Chapman & Aspin, 2013). In the context of teachers' PD, an Organisation for Economic Co-operation and Development's (OECD) report emphasises the need for teachers to improve their competencies across their career span (Coolahan, 2002). These competencies are varied and include subject and pedagogical knowledge, skills, attitudes and professional identity (Kwakman, 2003; Kyndt et al., 2016; Lohman, 2006). Informal learning allows teachers to meet their PD requirements as unpredictable learning needs arise. This has been

described as *just-in-time learning* (Greenhalgh & Koehler, 2017; Hamel et al., 2012; Jackson, 1999; Jones & Dexter, 2014). A study by Marsick and Watkins into 'Informal and Incidental Learning in the Workplace', concluded that 83% of what employees learn came through informal or on-the-job learning (Marsick & Watkins, 2015). This suggests that informal learning is not only widespread but may also play an important role in teachers' PD. Informal learning in this context is understood as any learning that takes place outside of formally organised PD activities (Eraut, 2000; Eshach, 2007; Marsick & Volpe, 1999; Teaching Registration Board of Western Australia [TRBWA], 2021; VIT, 2019). Such learning activities may include for example: reading, experimenting, reflecting, and collaborating (Kwakman, 2003, p. 155). The most potent motivators for teacher learning are internal, such as the desire for increased job satisfaction, self-esteem, and quality of life (Knowles et al., 2014; McMillan et al., 2016). These motivators draw attention to the importance of teachers' autonomy and agency in determining the outcomes of PD activities (Kwakman, 2003; Darling-Hammond et al., 2017; Forsberg & Wermke, 2012; Korthagen, 2017). Teachers' perceived sense of autonomy and agency are necessary components in forming and maintaining teacher identity (Badia & Iglesias, 2019; Chung-Parsons & Bailey, 2019; Deneroff, 2016; Rushton, 2021).

While informal learning has some formal recognition (OECD, 2019; TRBWA, 2021; VIT, 2019), unlike formal PD, only a scarce amount of research has been undertaken to examine the role of informal learning in teacher PD (Kahraman et al., 2021; Kyndt et al., 2016). This could possibly be due to the unstructured nature of informal learning, making it difficult to measure and assess (Cerasoli et al., 2018). To date, various critical questions remain unanswered. It is unclear what informal learning resources secondary school science teachers are accessing, as well as the extent and purposes for which these resources are accessed (Kahraman et al., 2021). Additionally, when viewed as a career-long/lifelong process, it is unclear how teachers' use of informal learning changes across their career path. This information is critically needed if we wish to develop a more comprehensive understanding of the science teaching profession and the professional teacher, the needs of science teachers, and the means by which to support them. From a practical perspective, closing these gaps may help school principals and organisers

of PD activities to develop more awareness regarding the informal PD needs of science teachers and facilitate these accordingly. The current study aims to close some of these gaps, by broadening our understanding regarding the ways by which teachers develop their professionality through informal learning.

The research is guided by the following questions:

1. How frequently are secondary school science teachers presently accessing:
   a. interactive media resources?
   b. non-interactive media resources?
   c. interpersonal communication resources?
   d. exhibitory and experiential resources?
2. What are the teachers' purposes in accessing the informal learning resources?
3. How do the number of years teaching experience relate to teachers' usages of the various informal learning resources?

In addition to the above three primary research questions, a fourth question arose through the process of analysis:

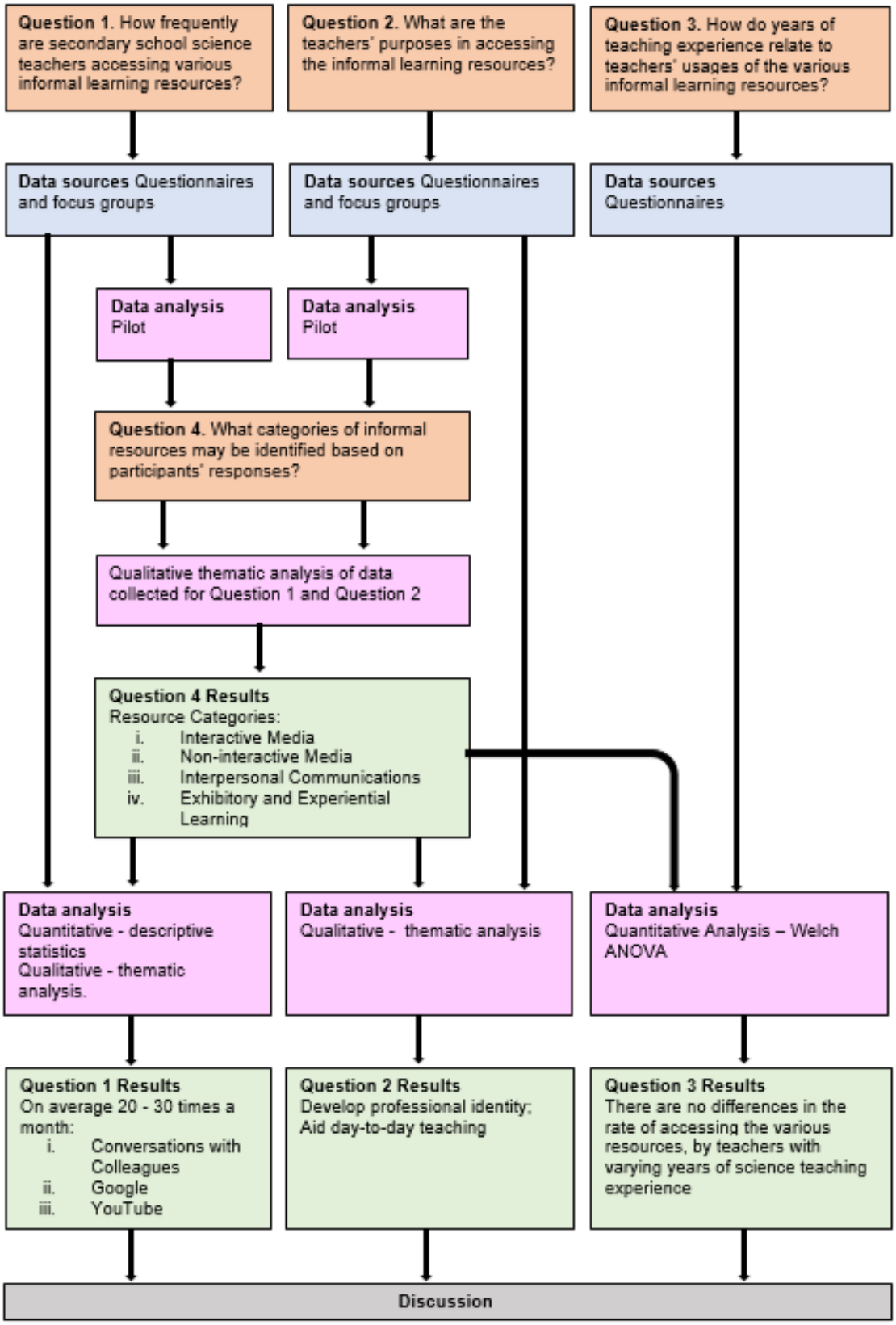
4. To what extent do the participants' responses to the *a priori* informal learning resource categories and their constituents, justify the use of these categories *posteriorly*?

1.1. The research process

The research process consisted of five stages, each building on the outcomes of the previous stage. Figure 1.1 presents this process along with its five stages.

Figure 1.1

Outline of the research process by research questions, data sources, data analysis, results and discussion



Two appropriate data sources were identified for addressing each question; these are: a written questionnaire and focus group discussions. *A priori* categories of informal learning resources were developed for the questionnaire. The pilot analysis of the qualitative and quantitative data for Question 1 and Question 2 gave rise to Question 4. From this analysis the *posteriori* categories of informal learning resources were derived. The data were then reanalysed under these *posteriori* categories to generate results for research Questions 1, 2 and 3. To provide results for Question 1, descriptive statistics and thematic analysis were applied to the data. To provide results for Question 2, thematic analysis was used. An analysis of variance was applied in the analysis of the quantitative data collected for addressing Question 3. Finally, these results were discussed in relation to the existing literature on informal learning and teacher PD.

The following chapter provides an overview of the literature that informs this research.

2. LITERATURE REVIEW

The following narrative literature review examines the major aspects related to teachers' development of their professionality. The chapter addresses sequentially the topics of teaching as a profession, science teacher identity, teacher learning, lifelong learning, formal PD, informal learning, communities of practice, and participation in PD across the career.

2.1 Teaching as a profession

This section discusses what a profession is, the characteristics related to teacher professionalism, a continuum of professionality, the role and impact of professional standards on teachers' professionality and teacher agency.

While the definition of what constitutes a profession is disputed (Sciulli, 2005) many researchers regard professions as the knowledge-based category of service occupations which usually follow a period of tertiary education and vocational training and experience (Evetts, 2011). Some of the characteristics associated with professions include: (i) professional training in which the practitioner holds not only factual or procedural knowledge, but is capable of explaining why something is done; (ii) socialisation into the values of the professional community and its standards of professional integrity and; (iii) being constrained by a code of ethics through which the individual professional is held to account by the profession itself through membership of a professional organisation (Beck & Young, 2005; Gamble, 2010).

Professionalism is the quality and commonality of the practice of members of a profession (Molla & Nolan, 2020; Sockett, 1993). When recognising teaching as a profession there have been attempts to categorise what constitutes teacher professionalism (Evetts, 2011; Hargreaves, 2000; Sachs, 2016). These include professionalism as: (i) an occupational value, (ii) an ideology and (iiii) a discourse of occupational change and managerial control (Evetts, 2011). Professionalism as an occupational value requires trust in the practitioner from both employers and clients and allows for autonomy and discretionary judgement by practitioners in complex cases (Evetts, 2011; Hargreaves, 2000; Hargreaves & Goodson, 1996). Professionalism as an ideology focuses on promoting teaching practitioners'

occupational self-interests through salary, status, and protection of occupational jurisdiction (Demirkasımoğlu, 2010; Evetts, 2011). Finally, professionalism as a discourse of occupational change and managerial control involves increased standardisation, formalised work procedures and practices, and managerial controls. It relies on externalised forms of regulation and accountability measures such as target setting and performance reviews (Evetts, 2011, p. 23).

Professionality is the individual expression of professionalism that signifies a certain quality that the public can expect from members of a profession such as teaching (Edling & Frelin, 2016; Evans, 2008). In teaching, professionality also refers to the knowledge, skills and procedures employed by teachers in the process of teaching (Hoyle, 1974; Samuelsson, 2019). Teacher professionality is contextualised and reflects the specific circumstances and interactions in which teachers find themselves (Frelin, 2015; Hargreaves, 2000; Solbrekke & Englund, 2011); and is central to the teacher's understanding of themselves as professionals (Egan, 2004). Professionality is therefore linked to a person's sense of constructing, holding, re-evaluating, and reconstructing a set of professional values, which will in turn impact on the ways in which they carry out their work in a practice setting (Dickerson & Trodd, 2020).

A continuum of professionality has been proposed from *restricted professionality* to *extended professionality* (Hoyle, 1974). At one end of the continuum the teacher uses intuition to make decisions, which is based on their day-to-day classroom experiences and practicalities. At the other end of the continuum the teacher values the theories underpinning pedagogy and adopts an intellectually based approach to the job (Evans, 2008). This continuum also reflects the professional autonomy and accountability in the teaching profession. The restricted end of the continuum is characterised by higher levels of accountability, whereas the extended end of the continuum is characterised by higher levels of professional autonomy. With teaching there exists a tension between teachers' own sense of professional authority on the one hand, and the authority systems exert through teacher professional standards and teacher accreditation bodies, on the other hand.

The development of professional standards for teachers has resulted in increased surveillance and measurement of teacher performance which reinforces the development of performance cultures (Goepel, 2012; Hult & Edström, 2016; Liew, 2012). The introduction of performance cultures suggests low level of trust in the professionality of the employees (Sachs, 2016). This in turn, impacts on the autonomy of teachers and how they enact their professional knowledge and judgement. The use of performance indicators along with the appropriation of commercial language and values suggests that teacher performance can be measured (Hoyle & Wallace, 2005; Mockler, 2005; Sachs, 2016). Thus, external evaluations of teachers' practice must make explicit the competencies and criteria to be measured when trying to codify and articulate in detail this kind of knowledge. Consequently, this tends to reduce and distort the complexity of teaching while diminishing teachers' sense of responsibility (Green, 2011; Hult & Edström, 2016). The contextual, emotional and iterative elements, which are so integral to teaching but which may not be quantitatively, or even qualitatively, measured may not be recognised by such restricted standards (Mockler, 2005). While some studies reported several negative consequences of external evaluations, it has been found that teachers generally complied with such evaluation requirements due to their sense of professional responsibility (Goepel, 2012; Hult & Edström, 2016; Liew, 2012).

In some countries and jurisdictions, it is perceived that governments are trying to direct teachers towards more technical work, with definable pre-packaged solutions and guidelines. Such attitudes towards teachers devalue their role as autonomous professionals capable of finding their own solutions to problems that arise (Goodson, 2005). The erosion of trust in teachers leads to risk-aversion practice and reduces the creativity of teachers, who have been found to prioritise trialled and tested practices that are more likely to be perceived as being successful by external evaluations (Mockler, 2005; Sachs, 2016). This undermines the notion of professional autonomy in favour of standardisation, leading teachers to become what Gamble (2010) describes as 'bureaucratic professionals' rather than real professionals. Bureaucratic professionals feel more accountable to authorities, rather than to the profession itself. This in turn reduces a teacher's sense of autonomy and agency.

While professionality is considered in the literature as ranging across a spectrum of attributes, in the context of this study, I use the term professionality in its broad sense as defined above by Hoyle (1974) and Samuelsson (2019). That is: The knowledge, skills and procedures employed by teachers in the process of teaching.

2.2 Science teacher identity

Identity theory defines identity as 'the kind of person one is seeking to be and enact in the here and now' (Gee, 2000, p. 13). The construct of identity facilitates discussion regarding the interconnectedness of the individual and the world. It addresses the role of the context and acknowledges the sociocultural nature of learning and development (Gee, 2000). *Socially situated identity* refers to the multiple identities people adopt, to be recognised as a certain 'kind of person' in a given context (Gee, 2000, p. 99). In seeking to be a certain kind of person a teacher is motivated to engage in PD beyond knowledge and skills (Avraamidou, 2014; Deneroff, 2016). Teacher identity offers a construct for studying teacher learning and PD beyond knowledge and skills and examines how 'learning transforms who we are and what we can do' (Wenger, 1999, p. 215). Teacher identity is: (i) socially constructed and constituted, (ii) dynamic and fluid, being constantly formed and reformed, and (iii) consists of various sub-identities that are interrelated (Avraamidou, 2014, p. 164).

Teacher subject specialism plays a role in a teacher's thinking about what kind of person they are and what kind of person they want to be. Secondary school teachers usually refer to themselves as teachers of specific subject areas and tend to separate themselves from other subject communities (Goodson & Cole, 1994; Tytler et al., 2011). The division of schools into discipline departments can serve as the primary site for social interaction, professional identity, and community (Trauth, 2019). This discipline focus can in turn provide the context for the teacher to think about learning, assessment, and their roles as teachers (Grossman & Stodolsky, 1995; Tytler et al., 2011).

Science teachers have more than a passing intellectual interest in their subject matter and dimensions of their identities are constructed in direct relation to science (Helms, 1998). There are three interrelated and overlapping dimensions of science identity: competence, performance and recognition. Competence refers to knowledge and understanding of science content. Performance refers to social performances of relevant scientific practices such as ways of talking and behaving. Recognition refers to recognising oneself and being recognised by others as a science person (Carlone & Johnson, 2007). Science identity is more of a personal identity as an affinity towards science enterprises, whereas science teacher identity can be differentiated as being a community identity in relationship to the profession (Glass, 2019). The participants in a diverse group of studies (Beijaard et al., 2000; Chung-Parsons & Bailey, 2019; El Nagdi et al., 2018; Irving-Bell, 2018; Woolhouse & Cochrane, 2015) found that science teachers tended to define themselves in relation to a shared identity around their subject matter and were therefore more likely to enact the norms and values associated with that identity rather than those of a general teaching identity (Rushton & Reiss, 2021). Science teachers see their identities as more closely aligned to their subject rather than as pedagogical experts (Glass, 2019). This divergence of science teachers from teachers of other disciplines justifies the choice of limiting the scope of this thesis to science teachers as opposed to teachers in general.

The development of a science teachers' identity is a complex and multidimensional process, which is influenced by multiple interactions and different kinds of relationships and experiences situated within various contexts. Subject matter is a critical determinant of identity development and subject matter features conspicuously in teachers' descriptions of themselves (Helms, 1998, p. 832).

2.3 Teacher learning

Teacher learning is inherent to the ongoing development of their professionality. Two important aspects of teachers' learning include the development of content knowledge (CK) and pedagogical content knowledge (PCK). Content knowledge is the teachers' understanding of the subject matter they teach. Pedagogical content knowledge involves a teacher having a knowledge of

students' subject-specific concepts and student misconceptions as well as a knowledge of subject-specific teaching strategies to assist students in understanding the causes of their misconceptions (Borko & Putnam, 1996; Kleickmann et al., 2013; Shulman, 1986; Van Driel & Berry, 2012).

Teacher learning over their career path forms an under-researched area within the field of science education (Bakkenes et al., 2010; Kennedy, 2016; van Driel, Berry, & Meirink, 2014). A search of the literature yields only fragmented information relating to characterizing teachers' learning over the span of their career. Within this sphere of paucity, the following aspects of teachers' learning are addressed: using metaphors as descriptors of teachers' learning; learning continuum ranging between individual-cognitive and situated-collective; and teacher growth.

One way suggested for understanding the diverse ways by which teachers learn and perform their work, is through metaphors. Mulholland and Wallace's (2008) review of this topic discusses four teacher metaphors: *computer database*, *craft, complexity,* and *change*. In the *computer database* metaphor, the teacher is viewed as a consumer of a range of discrete PD activities with each PD plugging into the teachers' knowledge database. The *craft* metaphor views the teacher as an independent artisan building up their repertoire of practice-based knowledge through cognitive apprenticeship. The *complexity* metaphor views the teacher as a social being working in a particular context, and the *change* metaphor represents how a teacher's knowledge grows, evolves or develops over time (Mulholland & Wallace, 2008; Wallace & Loughran, 2012).

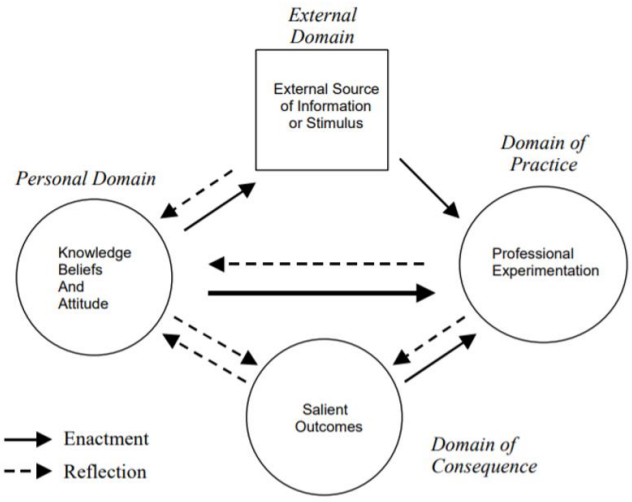
Mulholland and Wallace (2012) suggest that metaphors can be viewed as forming part of a continuum between the individual-cognitive and the situated-collective perspectives of teacher learning. The individual-cognitive perspective suggests that once encountered with a new learning situation, the individual draws on their prior knowledge to make the new experience understandable (Gillani, 2003; Yilmaz, 2011). Experiencing a new event, situation, or learning environment can lead to contradictions in a person's present understandings. This cognitive conflict between prior knowledge and new experience can take place without conscious awareness. In this regard, teacher learning is affected by the teachers'

thoughts, feelings and motivations (Korthagen, 2017). The situated-collective perspective regards learning as social in nature and situated in particular physical and social contexts (Putnam & Borko, 2000, p. 4). Teacher learning can occur in a variety of situations, including: during practice in their classroom, conversations with colleagues, counselling a child, or PD courses and workshops (Borko, 2004, p. 4). Some teachers can perceive their workplace as either enabling or constraining their learning. School factors such as teacher collaboration, resources for learning, and school climate all affect how teachers learn (Admiraal et al., 2016; Louws et al., 2017).

Another way for understanding teachers' learning is by focusing on teacher personal growth (Clarke & Hollingsworth, 2002; Kagan, 1992). This approach suggests that change occurs through the interaction between the processes of reflection and enactment. Within these processes there are four domains that comprise the teacher's world. These are: (i) the personal domain, comprising of teacher knowledge, beliefs, and attitudes, (ii) the domain of practice, comprising of professional experimentation, (iii) the domain of consequence, comprising of salient outcomes, and (iv) the external domain, comprising of sources of information, stimulus or support (Clarke & Hollingsworth, 2002). The interconnectedness of these domains is shown in Figure 2.1. Clarke and Hollingsworth (2002) suggest that there are multiple growth pathways between the domains (p. 951).

Figure 2.1

Interconnected model of teacher professional growth



Note: From "Elaborating a model of teacher professional growth" by Clarke & Hollingsworth, in *Teaching and teacher education, 18*(8), 947-967, p. 951 (2002) https://doi.org/10.1016/S0742-051X(02)00053-7.

Teachers' learning is a complex multidimensional process. It involves continuous reflection, adjustments and growth, occurrence over multiple settings and interactions between the external sources of information, the self and the situated-collective.

2.4 Lifelong learning

Lifelong learning is a continuous process in which individuals retain and develop their life-based conduct, knowledge and skills through both formal and informal learning (Coolahan, 2002; Demirel, 2009). During the 1990's, research on lifelong learning began to emerge. The OECD's *Making Lifelong Learning a Reality for All* report (OECD, 1996); and, UNESCO's *Learning: the Treasure Within* report (Delors, 1998), suggest that people are living in an age in which demands are complex and rapidly changing. People also need to engage in individual, communal and global learning throughout their lifespan (Chapman & Aspin, 2013). The field of lifelong learning is concerned with the acquisition of skills and competencies necessary for the development of general capabilities and specific performance of given tasks (Toomey et al., 2004). A report for the OCED Directorate for Education on *Teacher Education and the Teaching Career in an Era of Lifelong Learning*,

emphasised that developing new skills and competencies such as adaptability, flexibility, self-reliance, teamwork and innovation as being necessary for teachers in the contemporary workplace (Coolahan, 2002, p. 8). Developing these skills and competences is an ongoing process. Lifelong learning can have a bearing on how workers adapt their general and specific knowledge of, and competencies in, new tasks (OECD, 1994).

In order to be a successful lifelong learner, individuals need to possess a number of characteristics that include self-knowledge, self-confidence, persistence and a positive view of learning. They also need good self-management skills, be able to manage time and effort effectively, know when and how to seek help, and how to collaborate with peers (De la Harpe & Radloff, 2000, p. 170). Lifelong learners also need to be able to control their learning by planning, monitoring, evaluating and adapting their learning (De la Harpe & Radloff, 2000).

Teachers need to be lifelong learners, regularly upgrading their competencies and keeping abreast of changes in curriculum and pedagogy (Wong, 2013). Teachers face two significant challenges in regard to lifelong learning. The first challenge is promoting lifelong learning among the students they teach; the second is pursuing their own lifelong learning through PD (Selvi, 2010). While skills for lifelong learning are recognised as being important, there is little evidence of teacher training programs explicitly teaching prospective teachers the skills for pursuing their own lifelong learning (Cornford, 2002; Sahin et al., 2010). Teachers' PD has traditionally been researched within formal settings. The next section elaborates on this aspect of teachers' professional growth.

2.5 Formal professional development

The following subsections discuss teacher PD in the context of accreditation, provision of formal PD from the providers' perspectives, characteristics of effective PD, measuring the impact of formal PD, and finally, teachers' participation in PD activities.

2.5.1 Professional development requirements for teacher accreditation

Policy-makers recognise that the quality of education provided by any education system is dependent on the quality of the teachers working within that

system (Guskey, 2002). Recruiting and retaining high-quality teachers is essential to any education system. Equally important is continuing to challenge and develop teachers already in the profession. A common theme that emerges in the literature regarding maintaining and improving teaching standards is the importance of teachers' PD (Desimone, 2009; Guskey, 2009; Loucks-Horsley et al., 2009; Richter et al., 2011). Professional development in teaching is regarded as developing competencies and keeping up-to-date with changes in curriculum and pedagogy (OECD, 2019; VIT, 2019).

Professional development is a requirement for continued teaching registration in many countries (OECD, 2019). Schools are generally obliged to provide opportunities for teachers to access formal PD in a number of different areas. This enables teachers to maintain their teaching registrations and improves teacher competency (Scheerens, 2010). Many countries impose a defined minimum number of hours of annual PD. For teachers in countries that have set minimum requirements, the requirement is most commonly five days per year (Scheerens, 2010).

According to their website, the VIT uses the term 'professional development (PD) in reference to teacher registration and the renewal process. The VIT refers to PD also as professional learning (PL)' (VIT, 2019). The VIT website defines professional learning as 'an ongoing process supported by planned learning activities and programs designed to enhance professional knowledge, practice and engagement' (VIT, 2019).

The VIT website states that it 'does not have a definitive list of required PD activities for renewal of registration' (VIT, 2019). It does, however, state that the PD undertaken must address at least one standard selected from each of the three domains of the Australian Professional Standards for Teachers (APST). These are: professional knowledge, professional practice and professional engagement. These domains are further divided into seven sub-domains. Table 2.1 presents these domains and sub-domains.

Table 2.1

Professional learning domains and sub-domains for maintaining VIT registration

Professional knowledge	Professional practice	Professional engagement
1. Know learners and how they learn 2. Know the content and how to teach it	3. Plan for and implement effective teaching and learning 4. Create and maintain supportive and safe learning environments 5. Assess, provide feedback and report on learning	6. Engage in professional learning 7. Engage professionally with colleagues, parents / carers and community

Note. Adapted from VIT, 2019

The VIT website contains a list of formal PD activities which includes attending seminars, conferences, workshops and online learning, PD days in the workplace, mentoring colleagues, action research projects, short courses, multi-session PD post-graduate study and research participation. The VIT's list of informal professional learning activities in which a teacher might participate includes professional reading, collegiate meetings/professional conversations, resource research, and participating in education-related boards, committees or panels. The VIT suggests ways for teachers to provide evidence of engagement in both formal and informal professional learning activities. For informal PD activities it suggests members can record dates and times of meetings or minutes of meetings, by logging activities on the *MyPD* function of the VIT website (VIT, 2019). While the VIT website differentiates between formal and informal learning activities, it recognises both forms of PD as being of equal value when counting towards the 20 hours of PD activities required by teachers each year to renew their registration.

The 2018-2019 Victorian State budget invested $2.8 billion in education, setting aside $22.1 million for PD workshops and teaching tools for teachers along with school leaders to improve literacy and numeracy in teaching practice (Department of Education and Training, 2018). This investment in PD is undertaken with the expectation that it will yield a return on investment through raised student performance and attainment (Loucks-Horsley et al., 2009) as well as teacher retention (Ashiedu & Scott-Ladd, 2012; Coldwell, 2017). From a post-professional perspective, this government investment reflects the trend toward standardization, accountability and control (Hargreaves, 2000). However, further examination reveals more nuanced perspective of PD as discussed in what follows.

2.5.2 Provision of formal PD: The providers' perspectives

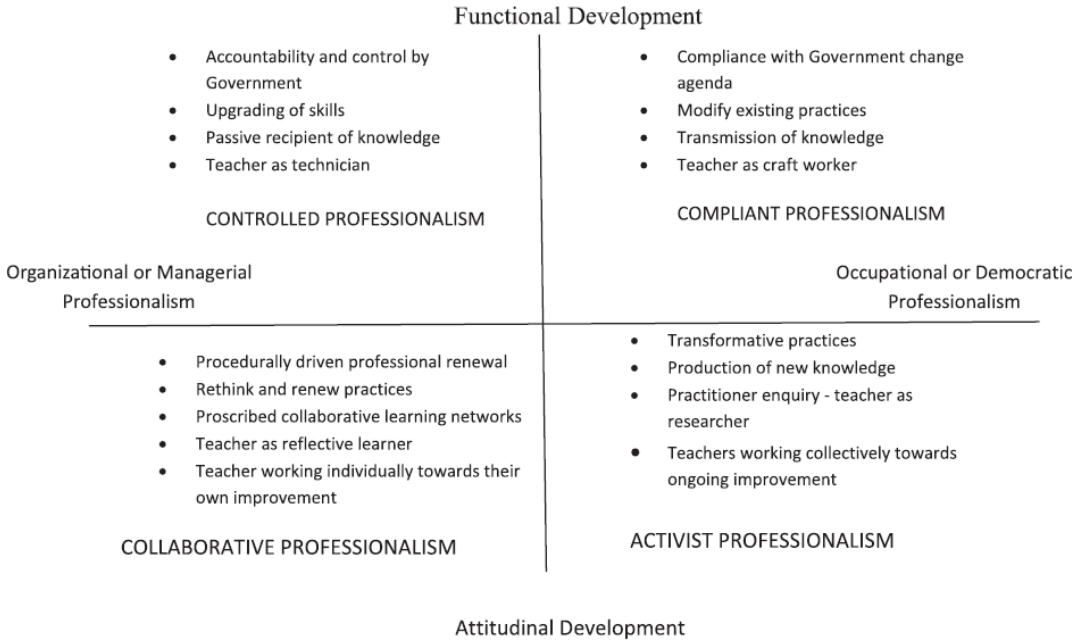
Teacher PD is often mandated by governments and teaching regulatory bodies to meet one of three imperatives: to align teachers' practices with educational policies, to improve the learning outcomes of students by improving the performance of teachers, and to enhance the status and profile of the teaching profession (Day & Sachs, 2004, p. 22).

Examination of research related to the provision of formal PD reveals three main topics under investigation. These are: purposes (Kennedy, 2005; Sachs, 2016); models (Villegas-Reimers, 2003); and, approaches to implementation (Loucks-Horsley & Matsumoto, 1999). The research conducted in relation to each of these topics will be discussed in what follows.

Formal PD activities are usually organised for a particular purpose. The purpose may be transmission of knowledge, or transformation of attitudes (Kennedy, 2005; Sachs, 2016). A transmission PD activity is where the purpose of the PD lies in preparing teachers to implement reforms such as a new curriculum. A transformation PD is one which supports teachers in contributing to and shaping education policy and practice (Kennedy, 2005; Sachs, 2016). Sachs (2016) argues that different types of PD contribute to the production and reinforcement of various kinds of teacher professionalism. Figure 2.2 presents Sachs (2016) categories of professionalism and PD.

Figure 2.2

Types of PD and teacher professionalism



Note. From "Teacher professionalism: Why are we still talking about it?" by Sachs, in *Teachers and teaching, 22*(4), 413-425, p. 421 (2016). https://doi.org/10.1080/13540602.2015.1082732

In Figure 2.2, *functional development* implies perceived weaknesses in individual teacher performance which need to be remedied (Kennedy, 2005; Sachs, 2016). It regards the teacher as a passive technician. It supports a skills-based, technocratic view of teaching, and is generally 'delivered' to the teacher by an 'expert', with the agenda determined by the deliverer, and the participant placed in a passive role (Kennedy, 2005; Van Driel & Berry, 2012; Van Veen et al., 2012). The focus is usually on coherence and standardization. It emphasises the completion of programs of study which may be accredited by awarding bodies (Kennedy, 2005). The purpose of *attitudinal development* is to encourage teachers to ask critical questions about their practice. Teachers are encouraged to do this through collaboration or through reflective enquiry (Kennedy, 2005; Sachs, 2016).

Once the purpose of a PD activity has been determined, the organisational model can be chosen. Professional development activities can be categorized into

organizational partnership models, and small group or individual models. These models are presented in Table 2.2.

Table 2.2

Organisational partnership and small group or individual professional development models

Organisational partnership models	Small group or individual models
Professional-development schools	Supervision: traditional and clinical
Other university-school partnerships	Students' performance assessment
Other inter-institutional collaborations	Workshops, seminars, courses, etc.
Schools' networks	Case-based study
Teachers' networks	Self-directed development
Distance education	Co-operative or collegial development
	Observation of excellent practice
	Teachers' participation in new roles
	Skills-development model
	Reflective model

Note. Adapted from "*Teacher professional development: an international review of the literature*: International Institute for Educational Planning Paris" by Villegas-Reimers, p. 70, (2003).

Organizational partnerships can require certain organizational or inter-institutional partnerships in order to be effective, whereas small group or individual models can be implemented on a smaller scale such as at a school or classroom level (Villegas-Reimers, 2003, p. 69).

From these organisation models, various approaches are used to implement teacher PD. These approaches include both formal PD activities and informal learning activities in the form of: (i) immersion, where participants work in their subject field for an extended period of time, (ii) curriculum, where teachers learn to implement new curriculum materials or teach a unit on a topic that is new to them or taught in a new way, (iii) examining practice, where teachers examine examples of students' work or teaching dilemmas and reflect on teaching situations, (iv) collaborative work, including partnerships with scientists, professional networks, coaching and mentoring, and (v) workshops, seminars and using technology (Loucks-Horsley & Matsumoto, 1999, pp. 263-265).

The OECD Teaching and Learning International Survey (TALIS) includes both formal and informal PD activities as options in its survey regarding teachers'

engagement in PD activities. The categories are: (i) formal PD activities, which include attending courses, seminars, conferences and formal qualification programs, both online and in person, (ii) collaborative activities, which include participating in learning communities and networks, observations, mentoring and peer coaching and (iii) self-directed study, which includes conducting research, reflection or professional reading (OECD, 2019). The high-level recognition, by the OECD, of informal learning as a form of PD, is of particular importance in the context of this study. It provides the rationale and legitimacy for the current study's focus on researching teachers' informal learning, as a form of PD.

2.5.3 Characteristics of effective professional development

For PD activities to achieve their goals, the activity should have certain characteristics which take into account what teachers already know and what they need to know as a consequence of participating in the PD activity (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009; Van Driel et al., 2001). There is general agreement that effective PD programs need to be cumulative, engaging secondary school teachers over a period of months or years and allow the opportunity to follow up on what has been learned, rather than being brief and sporadic activities (Birman et al., 2000; Borko, 2004; Corcoran, 2007; Darling-Hammond et al., 2017). There is particular criticism of short duration PD activities despite these being the most common form of PD activity that is provided (Darling-Hammond et al., 2017; OECD, 2019; Villegas-Reimers, 2003).

Villegas-Reimers (2003) produced a list of seven characteristics that a PD activity should possess for it to be effective. It should: (i) be based on constructivism rather than on a transmission orientated model, (ii) be a long-term process rather than one-off presentations or experiences, (iii) take place within a particular context and relate to the daily activities of the teachers, (iv) be linked to school reform and not merely skills training, empowering teachers as professionals, (v) regard the teacher as a reflective practitioner with prior knowledge, (vi) be collaborative, not just with other teachers but with administrators, parents and other community members, and (vii) look different in diverse settings (pp. 13-15). For the final characteristic, Villegas-Reimers (2003) acknowledges that 'there is not one

particular form or model of PD that is better than all others and which can be implemented in any institution, area or context' (p. 15). Other authors have produced similar lists regarding effective PD (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009; Jacques et al., 2017; OECD, 2019; Walter & Briggs, 2012).

Subject content focus is often mentioned as characterising effective PD (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009). Science teachers respond positively to PD opportunities that engage them as science professionals who are responsible for identifying their own development needs, rather than technicians who need to be upskilled in a generic way (Schuster & Carlsen, 2009).

In addition to learning science content during PD activities, some studies suggest that science teachers enjoy participating in research with scientists as a source of PD (Dresner & Worley, 2006; Koomen et al., 2014; Tanner, 2000). Collaborating with scientists increases a sense of collegiality among the teachers and scientists. These collaborations also increase collegial interactions between like-minded science teachers which, in turn, provides them with opportunities to discuss pedagogy-related issues (Aslam, Adefila, & Bagiya, 2018; Dresner & Worley, 2006). Fostering collegiality and common purpose among a group of science teachers is easier when they have a common interest such as participating in a research project with a scientist (Dresner & Worley, 2006). However, while some studies appear to provide evidence that science teachers working with scientists is an effective PD strategy, it may be that in reality those teachers who engage in research with scientists are already motivated to do so and thus find value in this activity (Dresner & Worley, 2006, p. 12).

Interactional and relational dynamics between participants in a PD program can affect the levels of engagement of each individual participant. The dynamics between the participants and the PD facilitator can influence the impact of a PD activity in either a positive way or a negative way depending on the capability of the facilitator (Finkelstein et al., 2019).

While some authors have produced checklists of characteristics for designing effective PD programs, these do not guarantee that an individual program will be successful in achieving its goals or that the absence of some characteristics will cause the program to be unsuccessful (Hill, 2009). An example of this is the criterion of *collaboration*, which is included in a number of lists of favourable PD characteristics. While collaboration may have a positive impact on PD effectiveness, some collaborative environments can stifle innovation and reinforce traditional practices rather than benefitting the participants (Fullan & Hargreaves, 1996; Little, 1990; McLaughlin & Talbert, 1993). Mandated collaborations may also result in participants feeling a sense of resentment towards a PD activity, rather than a genuine sense of collegiality (Hargreaves, 2000; Van Driel & Berry, 2012).

There are also concerns that not all ineffective PD is benign. In some cases, too much PD can decrease instructional coherence. This can occur if PD materials undermine or contradict district-adopted curricula and instructional approaches (Hill, 2009, p. 472). Opfer and Pedder (2011) recommend applying the *Goldilocks Principle* when viewing characteristics of effective PD. They suggest that for characteristics such as sustained duration, the PD activities should only be so long so as to encourage development and not cause fatigue.

Other limitations to effective PD activities include disempowerment of teachers due to some top-down approaches where teachers feel detached from the process of deciding what should be included in the PD (Butler & Schnellert, 2012; Gemeda et al., 2014; Roseler & Dentzau, 2013; Van Veen et al., 2012). As a consequence, some teachers feel disconnected from the subject matter of PD activities and can find such activities unhelpful or irrelevant (Bayar, 2014, p. 323; Schuster & Carlsen, 2009).

In the literature reviewed, a notable thematic insight is that teachers seem to find less value in time-consuming, top-down models of PD (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009; Korthagen, 2017). In science teacher research for example, teachers responded more positively to collaborative environments, where they are positioned as peers, rather than juniors or students. The literature appears to suggest that autonomy

when choosing PD activities is important to teachers (Czerniawski, 2013; Kwakman, 2003). Teachers' choices of PD activity can be seen as expressions of what they perceive as important knowledge and effective PD activities need to focus on teachers' individual needs (Darling-Hammond et al., 2017; Forsberg & Wermke, 2012; Korthagen, 2017; Thomson & Turner, 2015).

Teachers are different, with different needs and backgrounds (Guskey & Yoon, 2009). Finding activities that can address the needs of a group of teachers in a single day or workshop is challenging, yet it seems to be the most commonly used type of PD (OECD, 2019; Teaching Advisory Council, 2016). The more flexible and open-ended learning opportunities offered by informal learning where teachers can participate in PD activities at any time and any place to address their own learning needs may increase the effectiveness of teachers' PD. The findings regarding what constitutes effectiveness in teachers' PD clearly indicate that informal PD plays an important role in enhancing teachers' professionality, and thus merits further research attention.

2.5.4 Measuring formal professional development

When designing PD activities, organisers also need to consider how they will evaluate whether or not a given PD activity was successful in meeting its objectives (Kennedy, 2016). Measuring teacher learning during a PD activity or as a result of a PD activity is difficult (Borko, 2004; Darling-Hammond et al., 2017; Desimone, 2009; Loucks-Horsley et al., 2009). Efforts at measuring the effectiveness of a PD program are often limited by the scarcity of high-quality instruments (Trygstad et al., 2014, p. 1). In many cases evaluation of the impact of PD programs relies heavily on teacher self-report (Fishman et al., 2003). The National Mathematical Advisory Panel's 2008 report and the US Department of Education's National Centre for Education Evaluation and Regional Assistance 2008 review of PD initiatives for literacy, both concluded that the majority of studies on the effectiveness of PD programs lack methodical rigor, are descriptive, and utilize simple pre- and/or post-test designs (Garet et al., 2008; Guskey, 2009; National Mathematical Advisory Panel, 2008). There is general agreement that assessment of the impact of a PD program should not be based solely on teacher attendance, compliance or satisfaction (Desimone, 2009; Guskey, 2009; Loucks-Horsley et al., 2009; Loucks-

Horsley & Matsumoto, 1999). These tools for measuring PD activities only reveal fragmented information regarding the effectiveness of teachers' efforts to enhance their professionality.

2.5.5 Teacher participation in professional development

The following section presents a review of teachers' participation in different PD activities, teacher PD for ICT skilfulness, teachers' motivation to participate in PD and the barriers that limit teachers' participation in PD activities.

The National Academy of Sciences (NAS) 2012 National Survey of Science and Mathematics Education of secondary teachers in the US surveyed participants on the type of PD activities they had attended in the previous three years. The PD types and percentage of participation were: (i) workshops (90%), (ii) professional learning communities (73%), (iii) the receiving of feedback (54%), and (iv) attendance at science teacher association meetings (44%) (Banilower et al., 2013; Teaching Advisory Council, 2016). These data are similar to those of the TALIS 2013 survey, which found that 85.7% of teachers attended courses/workshops in the previous 12 months. The courses/workshops were conducted at an average rate of four days during the 12 months (OECD, 2014).

For many teachers the use of information and communication technology (ICT) in schools has increased during their teaching career. Some teachers may have entered the profession when both personal ICT use, and ICT use in the workplace were more limited. Others may be described as *digital natives,* people who have grown up surrounded by the ubiquitous use of ICT both in school and the wider world (Prensky, 2001). The increasing availability of digital and mobile technologies has provided teachers with access to large amounts of information which, in turn, generates many learning opportunities (Abedi et al., 2021; Curran et al., 2019; Lemmetty & Collin, 2020). Effectively using ICT in the classroom is a challenge currently facing education systems. Being exposed to new technologies will not improve student learning without the mediation and training of teachers (Howells, 2018; Peña-López, 2015).

The TALIS 2018 survey, reported 60.4% of participants in OECD countries engaged in organised PD activities on ICT skilfulness. The TALIS results for

individual countries found that only 39.3% of Australian teachers surveyed reported feeling prepared for using ICT in teaching. Of the surveyed Australian teachers, only 11.4% reported a high need for further PD on ICT for teaching (OECD, 2019). It is interesting to note here that while less than half of the surveyed teachers felt prepared to use ICT in their teaching, only 11.4% expressed a need for further formal PD. This discrepancy may suggest that teachers are learning ICT skills through informal learning rather than formal PD activities. It may be that when teachers are given the basic tools to engage with ICT, they use these tools to informally learn further ICT skills rather than look to formal PD activities (Carlson & Gadio, 2002; Mushayikwa & Lubben, 2009). Research into the use of online communities as the source of PD for 98 teachers in Australia found that 64% of the respondents indicated that their ICT skills were self-taught through trial-and-error, and 13% indicated that these were gained through work-based learning, which may include mentoring from other teachers or help from their students (Duncan-Howell, 2010). A review of ICT uptake by teachers provides some indication that informal learning plays a major role, most likely larger than the role of formal PD in enhancing teachers' ICT skilfulness (Duncan-Howell, 2010).

There are a number of factors which influence teachers' engagement in PD activities. Kwakman (2003) grouped these into personal factors, task factors and work environment factors. Within these subcategories, five personal factors, five task factors and three work environment factors were identified. These categories are listed in Table 2.3.

Table 2.3

Factors affecting teacher participation in professional learning activities

Personal Factors	Task Factors	Work Environment Factors
Professional attitudes	Pressure of work	Management support
Appraisals of feasibility	Emotional demands	Collegial support
Appraisals of meaningfulness	Job variety	Intentional learning support
Emotional exhaustion	Autonomy	
Loss of personal accomplishment	Participation	

Note. Adapted from "Factors affecting teachers' participation in professional learning activities" by Kwakman, in *Teaching and teacher education, 19*(2), 149-170 (2003).

The first three *personal* factors were derived from *Adult Learning* theory and relate to an individual's interest in self-directing their learning and what they view as the value of the PD activity (Kwakman, 2003). The fourth and fifth *personal* factors are derived from *Work Stress* theory developed by Karasek (1990) where the teacher feels compelled to participate in a PD activity due to the stress they feel towards their job and their perceived need to keep up with the demands of their job.

In Kwakman's (2003) model, *task* factors relate to the social psychological model of *Work Stress* which proposes that: 'stress as well as learning result from the combined effects of job demands and the discretion permitted to the worker on how they meet these demands' (p. 157). The *work environment* factors include the school culture and how it recognises and supports PD of its teachers whether or not participation in PD activities is appreciated and intentionally stimulated by the school culture and work environment (Kwakman, 2003, p. 157).

McMillan et al. (2016) found that for teachers engaging in PD, financial incentives, while appreciated, do not necessarily have much impact on teacher motivation to participate. While in some cases teacher motivation to engage in PD activities may be the limiting factor in the amount and type of PD undertaken, some teachers find barriers to their participation in PD activities even when they are motivated to undertake PD. The TALIS 2013 survey reported seven barriers to participating in PD. These are: (i) conflict with work schedule (58%), (ii) suitable PD not available (24.6%), (iii) family responsibilities (32.7%), (iv) too expensive (38.8%), (v) lack of employer support (23.9%), (vi) not having the required pre-requisites (6.5%), and (vii) no incentives for participation (39.6%) (OECD, 2014).

The literature stresses on one hand, the importance of PD and presents teachers' expression of their need for more PD (OECD, 2014). On the other hand, certain studies highlight the limitations and the ineffectiveness of formal PD activities (Guskey, 2009; Hill, 2009). For PD activities to be effective, they need to focus on teachers' individual needs and recognise, and build on, teacher's prior knowledge and understanding (Avalos, 2011; Birman et al., 2000; Corcoran, 2007; Darling-Hammond et al., 2017; Desimone, 2009). Many PD activities are delivered in a generic way, with little recognition of the participants' learning priorities, leading in some cases to the participants' disengagement. Teachers value opportunities for

directing their own learning (Kyndt et al., 2016; Lohman, 2006). Of particular interest to the current study is informal PD which offers teachers an opportunity to express their autonomy and agency in meeting their learning needs. While the literature reveals that teachers' informal learning is regarded as a form of PD (OECD, 2019; VIT, 2019); most evaluation to date focusses on the formal type of PD. In what follows, the scope and characteristics of *informal learning* are discussed.

2.6 Informal learning

This section presents an overview of informal learning. It discusses the difficulties involved in defining informal learning, informal workplace learning models, the categories of informal learning activities that teachers engage in as a source of PD, the purposes and outcomes of teachers engaging in informal learning, and teachers' motivations for engaging in informal learning activities.

2.6.1 Defining informal learning

Defining informal learning has proved difficult for many researchers and appears to have different meanings in different contexts. Some definitions of informal learning have their context in Informal Workplace Learning (IWL) (Beckett & Hager, 2005; Billett, 2002; Decius et al., 2021; Eraut, 2000; Hodkinson & Hodkinson, 2001). Other definitions of informal learning are in the context of adult education and lifelong learning (La Valle & Blake, 2001; Livingstone, 2001). Another context is predominantly political, which focuses on the political dimensions of formality and informality in learning, what is learned, who determines the content of learning, and what are the purposes of learning (European Commission, 2001).

For some researchers, informal learning is any learning that takes place outside formal education, but for others there are a number of criteria within which informal learning needs to fit before it can be categorised as such. These criteria include location of learning, degree of structure or curriculum, intention to learn, opportunity for certification, presence of a facilitator, learner voluntarism and/or learner agency (Beckett & Hager, 2005; Eshach, 2007; Hodkinson & Hodkinson, 2001; Livingstone, 2001). In regard to location of learning, definitions of informal

learning include learning that takes place in designed environments such as museums, and science-based facilities such as zoos and aquaria (Bell et al., 2009; Shaby et al., 2016). These environments are collectively referred to as *informal science education institutes* (Anderson et al., 2006; Braund & Reiss, 2006; Stocklmayer et al., 2010; Tal & Dierking, 2014). Confusion arises with these definitions as it becomes unclear what the authors mean by informality, whether it is the informality of the setting or the informality of the access to knowledge that is the determining factor when describing informal learning (Sefton-Green, 2004).

A number of terms have been used to refer to learning outside of formal settings. Terms used instead of *informal learning* include: *non-formal* learning, *free-choice* learning, *experiential* learning, *self-directed* learning, *incidental* learning, *tacit knowing, out-of-school* learning, *lifelong science* learning and *public understanding of science* (Dierking et al., 2003; Marsick & Watkins, 2001). Some studies use *informal education* interchangeably with *informal learning* (Dierking et al., 2003); and others differentiate between them (Eshach, 2007; Livingstone, 2001). The lack of agreement in regard to both the names and definition of informal learning in education scholarship causes these terms to remain ambiguous and loosely defined.

In their early work on informal and incidental learning in the workplace, Marsick and Volpe (1999) stated that informal learning could be conceptualised by the following characteristics: (i) integrated with daily routines, (ii) triggered by an internal or external jolt, (iii) not highly conscious, (iv) haphazard and influenced by chance, (v) an inductive process of reflection and action, and (vi) linked to learning of others (Marsick & Volpe, 1999, p. 5, Table 1.1). They suggested that informal learning: ‘arises spontaneously within the context of real work’ and that by its nature cannot be pre-programed (Marsick & Volpe, 1999, p. 4). This characterisation of informal learning as ‘haphazard and influenced by chance’ (Marsick & Volpe, 1999, p. 5) seems to exclude learning that is intentional or structured learning, such as purposefully going to the zoo to gain information about animals. There also seems to be a contradiction between ‘not being highly conscious’ and ‘being as a result of reflection and action’ (Marsick & Volpe, 1999, p. 5).

Schugurensky (2000) uses intentionality and awareness to distinguish between three informal learning situations: (i) *self-directed learning*, undertaken intentionally without the assistance of an educator, (ii) *incidental learning*, that is undertaken after an experience in which the learner becomes conscious of learning something but without any prior intention to learn and (iii) *socialization*, that is the accumulation of attitudes and behaviours that occur in everyday life where the learner has no conscious intention of learning them and is not aware that they have learned something (pp. 2-5).

Livingstone (2001) developed a typology related to the terms: *formal education*, *non-formal education*, *informal education and training,* and *informal learning*. He identifies six structural characteristics of learning and differentiates these accordingly. Malcolm et al., (2003) organised these characteristics, as presented in Table 2.4.

Table 2.4

Livingstone's (2001) categorisation of formal education, non-formal education, informal education/training and informal learning

Structural characteristics	Formal education	Non-formal education	Informal education/training	Informal learning
Knowledge structure	Curriculum – pre-established body of knowledge	Organised curriculum	No sustained reference to curriculum	No externally organised curriculum
Knowledge status	Rational cognitive	Partly pre-established, partly practical	Situational and practical – e.g. job skills, community development activities	Situational and practical
Mediation of learning	Teacher/elder	Teacher	Teacher, trainer, coach, mentor, often experienced co-worker – 'showing how'	No direct reliance on teacher
Location	Schools, etc.	Adult education courses/ workshops	Incidental and spontaneous situations, often at work	Anywhere – but often in employed, voluntary and unpaid work as well as leisure activities
	Indigenous communities	Employer training programs		
Primary agency	Teacher/elder	Learner	Teacher	Learner
Learner voluntarism	May be low – teachers designate learners as requiring knowledge	High – self-determined	Usually high	High when intentional

Note. Adapted from "Informality and formality in learning: a report for the Learning and Skills Research Centre" by Malcolm, Hodkinson & Colley in Learning and Skills Research Centre, p. 27, Figure 9 (2003).

Some researchers acknowledge that formal and informal learning can occur simultaneously (Falk, 2005; Malcolm et al., 2003; Sefton-Green, 2004). Others also suggest that few formal learning situations occur without some level of informal learning occurring concurrently, regardless of whether the informal learning is intentional or not (Dierking & Falk, 2016; Hofstein & Rosenfeld, 1996).

The review of informal learning definitions has informed the development of a working definition for this study. The literature review reveals that most informal learning definitions are contextual to the studies in which they are applied (Malcolm et al., 2003; Sefton-Green, 2004). Similarly, in the current study the applied definition is contextual to the study setting and applies specifically to secondary school science teachers. It is also defined primarily as the opposite to formal learning, meaning any learning activity that is not part of a formally organised PD activity (Eraut, 2000; Eshach, 2007; Marsick & Volpe, 1999). For the purposes of this research, there is no inherent need to differentiate between aspects related to conscious *versus* unconscious, intentional or incidental, and the location or mode of the learning activity. This study will be guided by the definitions used by the TRBWA and the VIT which describe teachers' informal learning as unstructured activities such as: planning professional learning; observing a colleague's lesson; taking part in professional or collegiate meetings; being involved in the development of policy or practice within the school or a wider context. It also covers the less tangible instances of learning such as: professional reading; reflecting on teaching practice; or visiting a museum or art gallery (Lloyd & Davis, 2018; TRBWA, 2021; VIT, 2019).

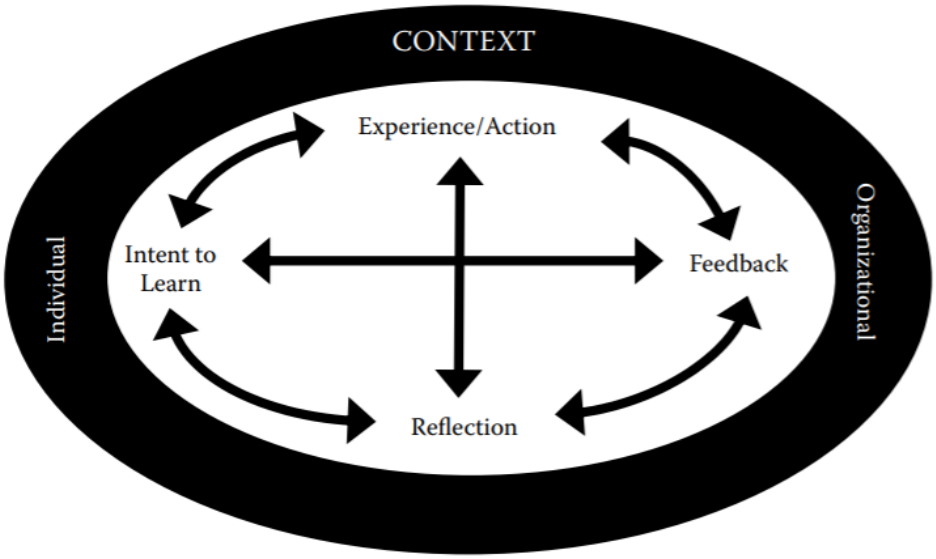
2.6.2 Informal workplace learning models

Typical informal workplace learning behaviours include applying one's own solutions to work problems, reflecting on work processes, sharing experiences with colleagues, and seeking feedback on one's own work results (Decius et al., 2019). Such activities are predominantly self-directed, intentional, and field-based (Cerasoli et al., 2018).

Tannenbaum et al. (2009) presented a four-point dynamic model of Informal Workplace Learning illustrated in Figure 2.3. It includes, (i) *Intent to learn*, improve, and develop, (ii) *engaging in an action* or an experience that involves the individual actively doing something, (iii) *receiving feedback* from the task itself or others and, (iv) *reflection* to seek understanding about one's experiences (Tannenbaum et al., 2009). They suggest that a person can enter the informal learning process at any point in the model and may experience one or more of the components, one or more times.

Figure 2.3.

Dynamic model of informal learning

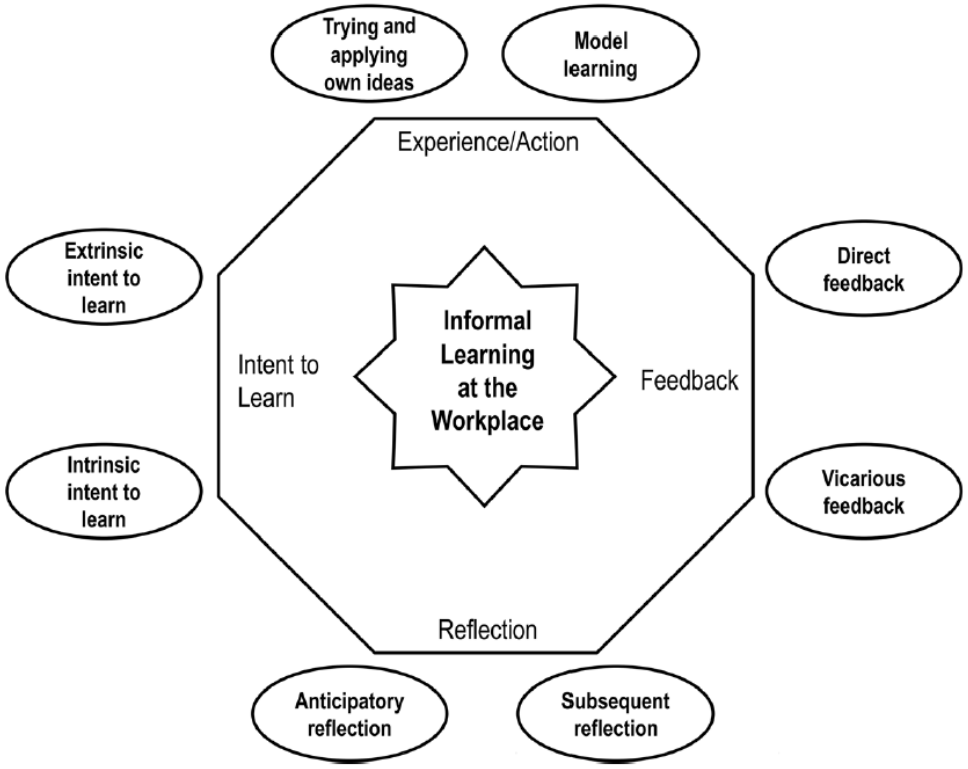


Note. From “Informal learning and development in organizations” by Tannenbaum, Beard, McNall & Salas in *Learning, training, and development in organizations* (pp. 323-351), p. 307 (2009). Routledge.

Decius et al. (2021) expanded on the model proposed by Tannenbaum et al. (2009) to add a secondary layer, with each point on the original model being divided into two sub-categories. The octagon model of informal workplace learning proposed by Decius et al. (2021) is presented in Figure 2.4.

Figure 2.4

Octagon model of informal workplace learning.



Note. From “Investigating the multidimensionality of informal learning: Validation of a short measure for white-collar workers” by Decius, Knappstein, Schaper & Seifert in *Human Resource Development Quarterly*, p. 11 (2021). https://doi.org/10.1002/hrdq.21461

In the octagon model (Decius et al., 2021) experience/action is divided into *trying/applying own ideas* such as experimenting with new solutions to problems and *model learning* where teachers observe the actions of colleagues. Feedback can be *direct feedback* such as receiving evaluations of one's own work performance or v*icarious feedback* where there is an exchange of experience without direct reference to one's own work performance. Reflection is divided into *anticipatory reflection* looking for solutions to problems before they arise and *subsequent reflection* where a worker considers possibilities for improvement after completion of a task. Intent to learn is divided into *extrinsic* and *intrinsic* intent. Intention to learn something new is related to a person’s motivation to engage in informal learning.

Work and workplaces are dynamic and the knowledge and skills that workers need is continually changing. This continuous change motivates workers to engage in informal learning to meet their professional needs.

2.4.3. Motivation to engage in informal learning

To thrive in the workplace individuals need to be capable of self-direction, and to know how to teach themselves (Kamenetz, 2010; Peters, 2013). In what follows, theories of motivation, and how these theories relate to teachers' motivation to engage in informal learning as a source of informal PD are presented.

Motivation to engage in informal learning activities can be influenced by characteristics such as: (i) stimulus to learn including work problems, experimentation, reflecting on oneself in relation to the job and learning from mistakes, (ii) the work environment such as work pressure, task variation, workload, organisational climate for learning and proximity to learning resources, and (iii) those relating to the worker such as social integration with managers and colleagues, self-efficacy, initiative, commitment to lifelong learning and love of content area (Doornbos et al., 2004; Kwakman, 2003; Lohman, 2006).

In general, adults tend to be self-directed to learning something new if they have an expectation that the object of learning will be valuable to them in their work situation, (Louws, Meirink, et al., 2017, p. 172). In *Adult Learning* theories, the term andragogy is used to describe the integration of learning to meet the demands of everyday work life through immediate problem-centred approaches to learning (Abela, 2009; Knowles, 1984; Merriam, 2001). Individuals are also likely to be autonomously motivated in a certain social context if they feel that other people in that context support their need for autonomy (Molla & Nolan, 2020; Roth, et al., 2007). This is related to *self-determination* theory, which suggests that the self is a growth-orientated entity and that individuals experience an inherent need for freedom of choice, in relation to meeting their learning needs (Ryan & Deci, 2000).

A person's motivation to engage in informal learning may arise from their authentic choices, personal values and interests rather than external pressures (Roth et al., 2007; Tadić et al., 2013). The research on work motivation refers to this as self-concordant work motivation. There are two different, but related types of

self-concordant motivation: integrated and identified. Integrated motivation reflects a fully autonomous motivation because it refers to engagement in work out of curiosity and interest (Kahraman et al., 2021; Ryan & Deci, 2000; Tadić et al., 2013; Vansteenkiste et al., 2009). Identified motivation for a work activity arises when an individual recognises the importance of an activity. The individual may not be spontaneously drawn to the activity, but they value and acknowledge the activity's importance (Roth et al., 2007; Ryan et al., 1993). In the current study I view a teacher expanding their existing science content knowledge through informal learning, as integrated self-concordant work motivation. I suggest that integrated self-concordant work motivation, like self-determination assumes that the self is a growth-orientated entity; motivated by curiosity and interest. In the current study I view a teacher self-teaching science content though informal learning as identified self-concordant work motivation. The teacher may not be spontaneously drawn to self-teaching content, but they recognise the importance of learning the science content so that they can teach it to their students.

To engage in informal learning, a person also needs access to informal learning resources. This could include the availability of colleagues to converse with, access to textbooks, subscriptions to certain media platforms or connection to the internet. The term *heutagogy* refers to the development of competencies as well as the capability to learn (Ashton & Elliott, 2007; Bhoyrub et al., 2010). In recent years there has been renewed interest in heutagogy theory due to what is perceived as its capacity to take advantage of the key affordances of the internet and other emerging technologies (Zheng et al., 2019). These affordances include: connectivity with others, information discovery and sharing, and adaptation of information as required (Blaschke, 2012). In the current study, these affordances may have an impact on the science teachers' frequency of use of the various informal learning resources presented to them.

2.6.4 Categories of informal learning activities accessed by secondary school science teachers

Studies on teachers' informal learning have identified categories of learning activities (Bakkenes et al., 2010; Dorie et al., 2012; Hoekstra et al., 2009; Kwakman, 2003). Kwakman (2003) identifies five categories of such activities.

These are: (i) *Reading*: studying subject matter literature, reading professional journals, studying teaching manuals, reading newspapers, (ii) *Experimenting*: helping students to learn study skills, preparing lessons individually, experimenting with new teaching methods, constructing lesson materials, constructing tests, working with new methods, (iii) *Reflecting*: supervising student teachers, receiving coaching or guidance, coaching colleagues, receiving pupils' feedback, (iv) *Collaborating*: storytelling, help – asking for help, giving help, sharing materials, ideas about innovation, instructional issues, ideas about pupil counselling, ideas about education, joint work, coordination, joining committees, preparing lessons, implementing innovations and (v) Not fitting into categories: counselling pupils, executing non-curricular tasks, performing management tasks, organizing extracurricular activities for pupils, classroom interaction with pupils, teaching in itself (Kwakman, 2003, p. 155).

In a study on science teachers' informal learning as a source of PD, Kahraman et al. (2021) found that teacher informal learning sources could be divided into personal sources and interactive sources. Interactive informal learning sources include active interactions with experienced teachers, consultant teachers, colleagues, school administrators, parents, and students, while passive interactions include online social networks, congress, conferences, courses, and seminars. Personal informal resources include the application of experience, utilising new methods and technologies, and projective activities. Personal informal resources also include written/visual personal sources such as educational websites, educational videos, articles, journals, books, documentaries, newspapers, mobile applications as well as official announcements and letters (p .83). A similar typology of learning sources was proposed by Huang et al. (2019) which contains five dimensions: (i) learning through media; (ii) learning through colleague interaction (iii) learning through stakeholder interaction (i.e., teacher educators, parents, friends, and others online); (iv) learning through teacher–student interaction; and (v) learning through reflection.

The typologies reviewed suggest that teachers engage in informal learning through interactive resources, non-interactive resources, interpersonal communication, and exhibitory and experiential resources.

2.6.5 Teachers' informal learning purposes and outcomes

There has been limited analyses of the purposes of informal learning activities within the context of teacher PD (Kyndt et al., 2016, p. 1112). A review of the literature identified three main purposes for which teachers access informal learning. These are: (i) increased subject knowledge, (ii) increased pedagogical knowledge and skills, and (iii) development of professional attitudes and identity (Kwakman, 2003; Kyndt et al., 2016; Lohman, 2006).

Regarding the purpose of increasing subject knowledge, Fraser (2010) found that teachers use informal learning to address gaps in subject knowledge after formal education had been completed. In her research into Facebook as a source of informal teacher PD, Rutherford (2010) found that 1.6% of posts to a teacher discussion Facebook page in Ontario Canada were in regard to subject content knowledge. This pertained to an educator's need to enhance their own knowledge of a specific content area through soliciting subject content from the discussion group members.

There are reports of informal learning purposes that are pedagogical in nature (Kleickmann et al., 2013; Kyndt et al., 2016; Richter et al., 2011). Pedagogical knowledge and skills include learning: (i) teaching skills, (ii) teaching methods, (iii) classroom management strategies, (iv) how to deal with paperwork, (v) multimedia use, (vi) equipment handling, (vii) preparation and planning, (viii) instructional program design and (ix) how to deal with emotional well-being to alleviate stress and strain, handle the workload, set realistic goals, deal with difficult situations and decisions, and motivate oneself (Kyndt et al., 2016, p. 1135).

Some studies discuss the contribution of informal learning to enhancing professional attitudes and identity. Through informal learning, teachers can form their teacher identity (Hodkinson & Hodkinson, 2005; McCormack et al., 2006; McNally et al., 2009); increase their self-confidence (Henze et al., 2009; McCormack et al., 2006; Verberg et al., 2013); and, acquire the competence to display professional or social behaviour (Burns & Schaefer, 2003; Burns et al., 2005; Hoekstra & Korthagen, 2011; Van Eekelen et al., 2006). They also learn about the politics within schools, the implicit and unwritten rules, and how to

navigate among them (Burns & Schaefer, 2003; Christensen, 2013; Flores, 2004; McCormack et al., 2006).

The review above reveals three main purposes which motivate teachers to access informal learning, (i) increased subject knowledge, (ii) increased pedagogical knowledge and skills, and (iii) development of professional attitudes and identity (Kwakman, 2003; Kyndt et al., 2016; Lohman, 2006). None of the studies that were reviewed, directly set out to measure and derive the categories of purposes. Unlike previous studies, the current study puts forward the aim to purposefully examine the science teachers' learning purposes. The above findings derived from the literature review are helpful as a benchmark for comparison.

2.7 Conversations with colleagues and communities of practice

Sociocultural theory suggests that the mental functioning of the individual is not simply derived from social interaction, but rather, learning by the individual can be traced to their interactions with others (Scott & Palincsar, 2013; Vygotsky, 1978). It suggests that learning takes place within a socio-cultural setting, where shared meanings are formed through negotiation in the learning environment, leading to the development of common knowledge (Voskoglou, 2019). Viewed through the lens of sociocultural theory, teachers' conversations with colleagues have the potential to provide an opportunity for professional learning or for developing micro-cultures that influence learning (Roxå & Mårtensson, 2015; Thomson et al., 2020). These conversations can take the form of formalised communities of practice or informal conversations in the staffroom, corridor or external to the school setting (Lantz-Andersson et al., 2018). They can be face-to-face or mediated by technologies such as social media platforms, online forums or a hybrid of both online and face-to-face modes (Vangrieken et al., 2017).

Communities of practice are groups of people who share a concern or a passion for something they do, and learn how to do it better, through interacting regularly (Brodie, 2021; Vangrieken et al., 2017). In communities of practice, learning can be the reason the community comes together or an incidental outcome of interactions amongst community members (Wenger, 2011, p. 11). Three

characteristics are necessary to constitute a community of practice: domain, community and practice. A *domain* refers to a shared competence that distinguishes the group members from other people, such as a shared interest. A *community* suggests that in pursuing their interest in their domain, members engage in joint activities and discussions, help each other, share information and build relationships that enable them to learn from each other. *Practice* refers to the necessity for members of a community of practice to be practitioners. They develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems, all of which takes time and sustained interaction. Some communities may meet mainly face-to-face, and others mostly online (Wenger, 2011, pp. 21-22).

Community membership allows us to define ourselves by what we are as well as by what we are not. These identities are dynamic and fluid, constantly being formed and reformed. Teachers need to create and recreate their image of themselves as members of a professional community (Sutherland et al., 2010). Being a member of a community of practice has been found to increase the likelihood of science teachers incorporating new content and practices into their courses. It has been linked in a positive way to identity development through raised confidence and a sense of collegiality. This emphasises the importance of interactions with others in defining one's science teacher identity (Pedretti et al., 2008).

Research into teachers' use of online communities, particularly those hosted on social media, have found that teachers engage in these communities for the following reasons: (i) *knowledge construction* through asking questions, giving opinions, exchanging ideas, sharing resources and reflecting (Visser et al., 2014); (ii) *knowledge sharing*, to share their knowledge, connect with other like-minded colleagues, and reach multiple audiences (Baran & Correia, 2014); and (iii) *collaboration*, as an opportunity for welcoming and fostering meaningful interpersonal relationships through the friendly, participatory culture of the community (Kelly & Antonio, 2016; Tour, 2017).

A study by Duncan-Howell (2010) found that teachers who are members of online communities spend between 1-3 hours per week participating in these online

communities, representing an additional 60-80 hours per year of professional learning. A significant proportion of these participants, 86.73%, agreed with the statement: ‘that participation in an online community represents meaningful PD’ (p. 336). The asynchronous nature, shared knowledge, and immediacy of responses appear to make online communities ideal for PD and professional learning (Macià & García, 2016).

Interactions in online teaching groups on social media platforms such as Facebook appear to show differences between large groups and smaller sub-groups (Lantz-Andersson et al., 2017). Members of smaller sub-groups seem to participate in online teaching groups to solve particular problems using specific tools and shared experiences. Large groups seem to be useful for pragmatic advice but do not appear to be a forum for reflection or feedback regarding teaching practice (Kelly & Antonio, 2016). As communities grow larger, disadvantages emerge such as the loss of collegial support, lack of contexts of communications as a consequence of too many contributions, lack of obligation, and fear of public criticism (Clarà et al., 2017; Kelly & Antonio, 2016; Lin et al., 2008).

Online communities can help strengthen face-to-face communities in what is referred to as *hybrid communities* (Brooks, 2010; Etzioni, 1999). The combination of online and face-to-face communities appears to achieve the best outcomes for communities of practice when compared to either online communities or face-to-face communities alone (Ardichvili et al., 2003; Donnelly & Boniface, 2013; Matzat, 2013; Sherer et al., 2003; Trust et al., 2016). Online communities of practice are not in a position to replace face-to-face communities of practice and care should be taken not to create false dichotomies between online and face-to-face communities (Trust et al., 2016). Instead, online communities of practice appear to offer an opportunity to improve the effectiveness of a face-to-face community.

There has been attempts to develop purpose-built spaces for online professional learning for educators such as Edmodo's subject communities (Lantz-Andersson et al., 2018; Trust, 2017). Aside from these, teachers in many countries also use popular social media tools such as Facebook (Kelly & Antonio, 2016; Patahuddin & Logan, 2019; Ranieri et al., 2012), Twitter (Carpenter et al., 2019;

Fox & Bird, 2017; Rehm et al., 2019) and Pinterest (Carpenter et al., 2018; Hu et al., 2018) for professional learning purposes.

While social media platforms can connect teachers beyond their individual schools, allow for personalized professional learning, and support resource sharing among educators (Biddolph & Curwood, 2016) they can risk context collapse (Kimmons & Veletsianos, 2014). Context collapse is particularly problematic for educators because of their professional responsibilities to various audiences (Cho & Jimerson, 2017). Teachers must also consider whether, how, when, and with whom to interact when using social media, and whether they are interacting personally and/or professionally (Carpenter et al., 2019; Fox & Bird, 2017). This concern has been compounded by the pervasiveness of social media where a teachers' personal and private behaviours and opinions may now be more likely to become publicly known (Warnick et al., 2016).

The next section addresses teachers' participation in PD in relation to their career stages.

2.8 Teachers' participation in professional development across their career

Progression across the teaching career typically consists of a number of stages such as: preservice, career entry or induction, competency building, stabilisation and finally career frustration, or wind-down prior to career exit (Day et al., 2007; Fessler & Christensen, 1992; Huberman, 1993). The number of years of teaching associated with each stage differs amongst studies. Richter et al., (2011) described three stages: beginning of the career (1-6 years teaching), middle of the career (7-30 years teaching), and end of the career (over 30 years teaching). Masuda et al. (2013) distinguish amongst four teaching career stages, which are: pre-service, beginning teacher (1-5 years teaching), mid-career (6-20 years teaching) and late-career (20+ years teaching). Louws, van Veen et al., (2017) use the categories of early career (1-7 years teaching), mid-career (8-19 years teaching) and late career (20+ years teaching).

Alternative approaches to discussing teacher career stages involve using the age of a teacher as a proxy for career stage of the teacher (Hildebrandt & Eom,

2011). It is unlikely, however, that all teachers of the same age have exactly the same number of years teaching experience and thus limits the usefulness of this approach as a method for discussing teacher career stages.

Studies on participation in PD activities across the teaching career indicate only minor differences (Evers et al., 2016; Hildebrandt & Eom, 2011; Masuda et al., 2013; Richter et al., 2011). Richter et al., (2011) found that teachers' uptake of in-service training starts at a low level at the beginning of the career, peaks at the middle of the career and decreases thereafter. While teachers early in their careers may have slightly lower PD participation rates than the career average, it is suggested that this may be a result of being 'overwhelmed with too much information' as they look to build their professional knowledge and skills (Masuda et al., 2013, p. 10). The greater than average uptake of PD activity by mid-career teachers, may also be motivated by extrinsic purposes such as movement on the salary scale. Hildebrandt and Eom (2011) found that teachers in their 30s were significantly more motivated by financial gain than their colleagues who were older than 40 years. Late-career teachers also have slightly lower PD participation rates than the career average (Richter et al., 2011). Masuda et al., (2013) found that late-career teachers would rather attend voluntary PD sessions that they felt were worthwhile rather than mandatory sessions, which they described as being 'shoved down their throats' (Masuda et al., 2013, p. 10). The lower engagement with formal PD activities by late-career teachers might also be explained by their greater than average engagement in collaboration with colleagues and professional reading (Richter et al., 2011). Louws, van Veen, et al. (2017) found that the learning goals of teachers differed at various stages of their career. Early career teachers' goals are related to classroom organisation, instruction and communication, whereas mid-career goals are framed in terms of increasing student understanding and developing PCK, with late career teachers being more interested in technological innovation and extracurricular tasks. Geeraerts et al., (2018) found that late career teachers were learning about technological innovation from younger colleagues. While younger teachers learned practical information, classroom management skills, self-regulation, and community building from their older colleagues.

Overall, teachers develop their professionality throughout their career span. While the form and goals of PD may change at various career stages, it seems that demography such as age or number of years teaching experience has little impact on teachers' rates of participation in PD activities. The current study aims to explore this question in relation to teachers' informal PD. Of particular interest in this context is the question of whether the types of resources and the frequency of use change across the career path.

2.9 Summary of the literature reviewed

The literature reviewed above examined various aspects related to science teachers' informal learning, in the context of PD. Beginning with formal PD, studies suggest that while this type of teacher learning is the most highly researched, its effectiveness seems limited (Guskey, 2009; Hill, 2009). Of particular relevance to the current study, are findings which highlight teachers' needs as professionals for autonomy and agency in directing their learning and developing their science teacher identity (Butler & Schnellert, 2012; Czerniawski, 2013; Gemeda et al., 2014; Roseler & Dentzau, 2013; Sachs, 2016). Science teachers prefer not to be positioned in a role akin to students (Schuster & Carlsen, 2009); and prefer formal PD activities in which they work side-by-side with scientists (Dresner & Worley, 2006; Koomen et al., 2014; Tanner, 2000).

A review of the literature related to teachers' PD reveals that notable organizations, such as the OECD and VIT, as well as many researchers, refer to teachers' PD as being inclusive of both formal and informal learning (OECD, 2019; Teaching Advisory Council, 2016; VIT, 2019). Unlike formal PD research, very few studies have been undertaken to examine the role of informal learning in teachers' PD. However, these studies provide a strong indication that informal learning plays a major role in enhancing teachers' professionality (Kleickmann et al., 2013; Kyndt et al., 2016; Masuda et al., 2013; Richter et al., 2011). Teachers are self-motivated and self-directed in their informal learning (Kwakman, 2003; McMillan et al., 2016; Mushayikwa & Lubben, 2009).

The review of research related to science teachers' professional identity provides some indication that teachers' motivation to participate in informal learning is derived from the need to continuously develop their professional identity (Avraamidou, 2014; Canrinus et al., 2011; Day et al., 2007; Helms, 1998). Similarly, this need is served through online and face-to-face participation in communities of practice (Duncan-Howell, 2010; Macià & García, 2016). Additionally, there is clear indication that teachers continue to develop their professionality across their entire career path as lifelong learners (Evers et al., 2016; Hildebrandt & Eom, 2011; Louws, van Veen, et al., 2017; Masuda et al., 2013; Richter et al., 2011).

Overall, the findings of this review strongly suggest that informal learning plays a critical role in science teachers' PD. It appears that this important role has thus far been mostly overlooked and its contribution has been underestimated. Critical information is still unknown in regard to science teachers' informal learning. The present study conducted a close examination of these issues, by applying a purposefully designed methodology effective in addressing the research questions. The following chapter describes the methodology.

3. METHODOLOGY

In this chapter the conceptual methodological framework for this research is presented, followed by the methods that were used to answer the research questions. The definitions of categories of informal learning resources used in the questionnaire, and the data collection and analysis are explained. The validity, reliability and trustworthiness of the data collection and analysis process are discussed. Finally, the ethical considerations for conducting the research are presented.

3.1 Conceptual framework

This research draws upon the post-positivist research paradigm using a pragmatic research approach (Phillips & Burbules, 2000). For the purposes of the present study a mixed methods design using quantitative and qualitative methods was applied (Creswell, 2013).

Post-positivism is a research paradigm that views truth and knowledge as conjectural. In the post-positivist paradigm, the researcher seeks to develop relevant, true statements through objective and competent enquiry (Creswell, 2013; Phillips & Burbules, 2000). Post-positivism was considered an appropriate choice of research paradigm for this study as it does not attempt to discern a single social reality.

Within the post-positivist paradigm, the pragmatic approach understands that knowledge occurs in social, historical, political and other contexts. A pragmatist utilizes methods that are effective in answering the research questions and 'sidesteps the contentious issues of truth and reality' (Feilzer, 2010, p. 8), and 'focuses instead on 'what works' as the truth regarding the research questions under investigation' (Teddlie & Tashakkori, 2003, p. 731). Pragmatists mix both quantitative and qualitative methods when mixing the two is beneficial (Creswell, 2013; Onwuegbuzie & Leech, 2005; Phillips & Burbules, 2000).

This study used a mixed-methods design rather than a purely quantitative or qualitative design. The combining of the two approaches helps to overcome the

limitations of each research design. Limitations of quantitative designs include difficulties in reliably integrating information across observations or cases (Kirk et al., 1986), and difficulties in assessing links and associations that occur between observations, cases, or constructs (Castro et al., 2010). Quantitative research can also be limited by its detachment from the context of a study (Moghaddam et al., 2003), a phenomenon referred to as *decontextualization* (Castro et al., 2010; Viruell-Fuentes, 2007). By comparison, a qualitative research design holistically examines a person's practices and attitudes within the context of their own environment. Creswell et al. (2003) describe the value of using a mixed methods approach is it offers the descriptive richness of text narratives as well as the precision in measurement and hypothesis testing afforded by quantitative approaches (Carey, 1993; Hanson et al., 2005).

In a mixed methods study, there are three strategies for data collection. These are: sequential, transformative and concurrent (Hanson et al., 2005; Terrell, 2012). In a sequential strategy, the collection and analysis of quantitative data is followed by the collection and analysis of qualitative data. For a transformative strategy there are two distinct data collection phases and either type can be collected first. Priority can be given to either or both data types. In a concurrent strategy, there are two concurrent data collection phases. Data are integrated either during the data analysis phase or during the interpretation phase. The interpretation notes either a lack of convergence or convergence that strengthens knowledge claims (Terrell, 2012).

The present study used a concurrent mixed methods design where both qualitative and quantitative data were collected simultaneously (Leech & Onwuegbuzie, 2009). A concurrent mixed method offers the opportunity for corroboration and cross-validation within a single study (Teddlie & Tashakkori, 2003). A concurrent strategy for data collection was chosen for this study as it requires less time to complete when compared to a sequential strategy or a transformative strategy (Terrell, 2012). In the current study the majority of the data collected, 70 of the 91 questionnaires, and both focus groups, were collected at science teacher conferences, limiting the time available for data collection to the dates of these conferences. After the data were collected, a pilot analysis of the

qualitative and quantitative data was conducted concurrently, which facilitated the recognition of potential anomalies. The results of the quantitative and qualitative data were then integrated to produce the Results chapter of the current study upon which the Discussion chapter is based.

In what follows, the research methods are presented and explained.

3.2 Methods

This section describes the data collection instruments used in this study, the information obtained through these instruments and their justification. The data collection process for these instruments is also explained. Finally, the categories of informal learning resources are justified.

3.2.1 Instruments

The present study aims to characterise the use of informal resources by secondary school science teachers. Two instruments were used for data collection: a survey questionnaire and a focus group protocol. In what follows, the instruments that were used and the categories used for grouping resources are described.

Survey questionnaires

The purpose of the survey questionnaire was to collect data regarding the participants' frequency of use of the various informal learning resources. The participants' purposes for accessing the informal learning resources were also collected, along with demographic data such as the number of years teaching experience and the Victorian Certificate of Education (VCE) science subjects, taught by the participants (see Appendix A for the Survey Questionnaire).

A written questionnaire method was chosen, as a questionnaire has the capacity to give definite answers to questions and produce reliable results especially when the participants do not find the questions too private or too threatening (Pratt & Loizos, 1992). Questionnaire data also provide the researcher with an opportunity to generalize the findings of a sample of responses from a population (Creswell, 2012).

Areas of inquiry in the questionnaire were developed and administered by the researcher as a semi-structured questionnaire. In a semi-structured questionnaire, the participants are asked to answer some closed questions and some open-ended questions. In closed questions the participant selects one, or more answers from the given alternatives (Synodinos, 2003). Structured, closed questions are appropriate for collecting answers where the replies are limited or clear-cut, such as demographic data (Simmons, 2001). Open-ended questions, however, were required for collecting some of the data, regarding the purpose for which teachers accessed informal learning resources.

Participants were asked to rate on a five-point Likert scale their frequency of use of the various informal learning resources. The 32 resources were organised in the following five categories: *interactive resources*, *non-interactive resources*, *interpersonal communication*, *exhibitory and experiential resources* and *printed materials*. On the five-point scale, 1 corresponds to never (i.e. zero times in a typical month), 2 to rarely (i.e. 1-10 times in a typical month), 3 to somewhat frequently (i.e. 11-20 times in a typical month), 4 to frequently (i.e. 21-30 times in a typical month), and 5 to very frequently (i.e. >30 times in a typical month). The participants were also provided with an opportunity to list other informal learning resources that they use under the category *Other*. An additional open question asked the participants to explain their purposes in using the various resources.

Further collection of demographic data allowed the comparison of the frequency of use rating of the various informal learning resources, to the teachers' career stages (see Appendix A).

3.2.2 Focus group discussions

The purpose of the focus group discussions was to elicit qualitative data regarding the participants' purposes in accessing the various informal learning resources.

Focus groups have the capacity to facilitate comparison and afford insights that may not be provided by other methods used in the study (Barbour, 2008). The interaction among the participants helps them to consider and reflect upon aspects of their daily life that are usually taken for granted (Morrison & Morrison, 1998). A

focus group allows the participants to recognise previously hidden parts of themselves in others (Crabtree et al., 1993); and can help the participants to explore and clarify their views in ways that would not be as easy to access in a questionnaire (Kitzinger, 1995).

In order to encourage the collection of detailed and relevant information regarding the research topic, it is important that the people involved are interested in the topic and that they are able to discuss it thoroughly (Acocella, 2012). Direct experience of a topic can motivate people to take part in a discussion and to interact with each other (Munday, 2006). Hence, focus groups are considered to be appropriate when the participants have experienced a similar professional or social context and feel equal to each other. If participants feel equal then they will feel more comfortable in expressing their thoughts more spontaneously (Acocella, 2012).

Two focus groups were conducted in this study. One focus group was held with 11 secondary school biology teachers at a biology teachers' conference, and a second focus group, with six secondary school chemistry teachers at a chemistry teachers' conference. The two focus groups were conducted in the same venue, one day apart. Each focus group session was conducted for 45 minutes. An attempt was made to organise a third focus group with physics teachers, but unfortunately, the physics teachers focus group did not attract enough participants to be conducted.

The meeting room for the focus groups had four tables, with four chairs at each table. The participants were invited to sit at a table of their choice. Each table was equipped with pens for writing and stimulus materials (see Appendix B for Focus Group Stimulus Materials). The focus group protocol consisted of five stages. Each of the five stages is discussed in what follows (see Appendix B for Focus Group Protocol).

Stage 1: The purpose of the study was explained to the participants of the focus group.

Stage 2: Participants were requested to make a list of the resources that they use to inform their science teaching and professionality, and the purpose of accessing

these resources. To facilitate this each table was provided with an A3 page with the categories of informal learning resources printed on them; these were: *interactive media*, *non-interactive media*, *interpersonal communications*, *exhibitory and experiential resources* and *printed materials*. The participants seated at each table were asked to write their lists as a small group. Each group had between two and four participants. Such small groups may afford an opportunity for all participants to talk and share their thoughts.

Stage 3: When each table of participants had completed the task of listing the informal learning resources that they used and the purpose for which they used these, the researcher asked a participant from each table to read out their list of resources to the whole focus group. The participants were then encouraged to share their thoughts on the resources with the whole focus group. The sub-groups were joined together into a larger group in order to generate diverse points of view.

Stage 4: The participants at each table were asked to rank, on the A3 stimulus sheet, the impact that each informal learning resource has on their teaching and professionality.

Stage 5: When the participants had completed this task, the full focus group was asked if there were any resources that they would like to see made available to teachers in the future to further support them in their teaching and professionality.

Upon analysis, it was realised that the data collected for Stages 4 and 5 was not comprehensive enough to address the aspect of impacts and need for additional resources. The participants did not seem to address the prompts in their responses. While the discussions conducted in Stage 4 did not address the question of impact, it was realised through the analysis that the teachers provided rich data related to the purposes of accessing the resources. These data were used in addressing Research Question 2: What are the teachers' purposes in accessing the informal learning resources?

All discussions taking place during the focus groups were recorded and transcribed. Additionally, the worksheets filled by the groups were collected for further analysis. These recorded discussions and written responses provided

qualitative, contextual data regarding the participants' use of informal learning resources.

3.3 Determining categories of resources

In preparing the survey questionnaire and the focus groups' protocol, there was a need to develop categories of resources, as a means for simplifying the questions and making these easily understood and unambiguous for the participants. Categories are also helpful in organizing the information conceptually. The literature does not provide any set of categories of informal resources used by teachers. Previous studies on teachers' informal learning practices have focused on specific informal learning activities but do not list categories of informal learning resources (Bakkenes et al., 2010; Kwakman, 2003; Tynjälä, 2008). Therefore, there was a need to develop categories of resources, in which various resources are grouped together.

The process of developing the categories of informal resources consisted of two stages. First, *a priori* categories were developed. These categories were based on my own preconceptions of which informal resources belonged in each category. These categories appeared in both the survey questionnaires and the questions in the focus group protocols. After the initial data analysis was completed, these *a priori* categories were regrouped to form *posteriori* categories of informal learning, based on the participants' responses. The new categories form a research outcome and are discussed in the Results chapter.

3.4 Data collection

3.4.1 Participants

The teachers involved in both the survey questionnaire and the focus group discussions participated voluntarily and were all VIT-registered secondary school science teachers, teaching biology, chemistry or physics in the state of Victoria, Australia, at the time of the data collection. All participants had been teaching for a minimum of one full academic school year when they completed the questionnaire.

All focus group participants completed the survey questionnaire prior to participating in the focus groups.

The questionnaire participants had an opportunity to identify their age category. All questionnaire participants completed this question. The number of participants in each age category is presented in Table 3.1.

Table 3.1

The number of participants for each age range

Age range in years	Number of participants
20-30	26
31-40	29
41-50	11
51-60	9
61-70	14
>71	2

The number of years teaching experience of the participants was also collected and is presented in Table 3.2.

Table 3.2

The number of participants for each range in years of teaching experience

Years of teaching experience	Number of participants
>1	9
2-5	26
6-10	20
11-20	14
21-30	12
>31	10

For the purpose of conducting a quantitative analysis it is important to identify the population in terms of its characteristics and size. The present study focuses on informal learning among the population of secondary school science teachers in the state of Victoria, Australia. A demographic report conducted by McKenzie et al. (2014) found that the mean age of secondary school teachers in Australia in 2013 was 45 years. While McKenzie et al. (2014) report the age profile of all secondary school teachers in Australia rather than secondary school science teachers in Victoria, Table 3.1 indicates that the median age of the teachers

sampled by the current study questionnaire was in the age range 41-50 years. McKenzie et al. (2014) found that in 2013 the percentage of male secondary school teachers in Australia was 40.8% and female was 59.2%. In the current study, 91 participants completed the questionnaire. Of these participants 57 identified as female and 34 identified as male, with no participant identifying as 'other'. Whence, the percentage of teachers who identified as male is 37.4%, and female is 62.6%. In respect to the characteristics of age and gender, the participants appear to be similar to those reported by McKenzie et al. (2014).

The size of the target population is needed in order to establish the precision and confidence level of the sample. A search for data regarding the number of secondary school science teachers in Victoria, and the corresponding tertiary qualifications of these teachers, revealed that this important information has not been collected so far by the Department of Education and Training or the Victorian Institute of Teaching (VIT). Efforts to obtain this information from other sources such as the Australian Office of the Chief Scientist, Science Teachers Association of Victoria (STAV) and the Australian Association of Science Teachers were not successful. The authors of a number of reports (Education Council, 2018; General, 2012; Innovation & Australia, 2017; Teacher Education Ministerial Advisory Group [TEMAG], 2014) have called for these data to be collected but as of the time of writing, the data are still not available.

There being a lack of official data, a calculation was performed to estimate the number of secondary school science teachers in Victoria in the various discipline areas. This estimate compared the data collected by Harris, Baldwin, and Jensz (2005) in *Meeting the demand for qualified science teachers in Australian secondary schools,* the McKenzie et al. (2014) report *Staff in Australia's schools 2013* and the DET (2020) *Victorian Teacher Supply and Demand Report*. Based on these reports the estimated numbers are: 1300 for biology, 1227 for chemistry and 1155 for physics (see Appendix C for the calculation and the associated assumptions). These estimates are likely to be slightly inflated as this calculation does not take into account teachers who teach more than one science subject. Evidence of this can been seen in the participants' responses to the questionnaire. In the questionnaire, 40 indicated that they teach biology, 53 teach chemistry, and

11 teach physics. However, twenty-two participants indicated that they teach more than one VCE science subject. These are: 14 who teach biology and chemistry, one who teaches biology, chemistry and physics, and 7 who teach chemistry and physics.

In order for the questionnaire to achieve a precision of ±10% with a confidence level of 95%, a sample size of 98 respondents is needed for a population of less than 4000 (Israel, 1992). The sample size of the current study of 91 participants affords a precision of ±10.12% with a confidence level of 95%.

For focus groups it is recommended that the size of the group be between six and 12 participants, so that the group is small enough for all members to talk and share their thoughts, and yet large enough to create diverse points of view (Krueger & Casey, 2014; Onwuegbuzie et al., 2010). In the current study, there were six participants in the chemistry focus group, and eleven participants in the biology focus group. Thus, both focus groups meet the recommended group size. The focus groups were organised to facilitate a high level of homogeneity by conducting separate focus groups for biology and chemistry teachers. In this way the participants shared similar professional contexts and were more likely to feel equal. Homogeneity in focus groups can help to uncover shared perceptions of population samples. Participants in each focus group all belonged to the same sub-group segment, in this case by the science subject they taught. This was done to facilitate an analysis of differences between the sub-group segments and increase the external validity of comparisons made between subgroups. This segmentation can also increase the likelihood of uncovering a pre-existing reality. Too much heterogeneity in the focus group participants could inhibit discussion as participants may feel unwilling to express themselves (Freeman, 2006; Krueger & Casey, 2014; Morgan, 1996). Nonetheless, certain participant heterogeneities still existed as the participants were of a range of number of years teaching experience, may have worked at different school types such as government schools or independent schools, and both male and female teachers were present in each of the focus groups.

3.4.2 Sampling

For the questionnaire, a convenience sampling technique was used. A convenience sampling technique involves obtaining responses from those people who are available and willing to participate. Convenience sampling is a non-probability sampling technique which can be used when respondents are chosen because they are easily accessible, or the researcher has some justification for believing that they are representative of the population. The primary weakness of this approach is that the people who are willing to participate may differ from those who are not willing to participate and so there is a risk that the sample is biased and not representative of the target population. However, this sampling method can be useful when the target population is very specific and of limited availability and where it may not be possible to rely on a random sample (Kitchenham & Pfleeger, 2002). The choice of convenience sampling is justified in the current study as the participants were from a specific target population and their attendance at the science teaching conferences offered an opportunity to access this target population.

For the focus groups' discussions self-selection sampling was used. A significant characteristic of this technique is that the research participants volunteer to take part in the research rather than being approached by the researcher directly (Sharma, 2017). The advantage of this technique is that the participants are more likely to be committed to take part in the study, which may encourage greater willingness to provide insight into the phenomenon being studied. However, a disadvantage of this technique is that the potential research participants volunteer to take part in the survey and may be more likely to introduce a degree of self-selection bias. The decision to participate in the study may reflect some inherent bias in the characteristics/traits of the participants (Sharma, 2017). The focus groups for the current study were offered in the form of one of the workshops available at the science teacher conferences and the participants self-selected to participate in the focus groups.

3.4.3 Recruitment

Of the 91 participants who completed the questionnaire, 70 were recruited at science teacher conferences. These conferences were chosen for recruitment

purposes as they are attended by a large number of the teachers targeted by this research. Potential questionnaire participants were approached by the researcher at the conferences and asked to participate. The remaining 21 questionnaire participants were recruited through snowballing techniques, where initial participants helped to recruit other secondary school science teachers known to them and who were interested in participating in the study.

An information sheet describing the purpose of the research and a consent form to sign were given to each participant by the researcher, along with a pen (see Appendix D for consent form and information sheet). The purpose of the study was explained to each participant and any questions that the participants had were answered by the researcher. Once the participants agreed to participate, they were presented with a printed questionnaire to complete. The questionnaire took approximately 20 minutes for each participant to complete. The participants completed the questionnaires individually and the researcher confirmed with participants that they were comfortable (agreed) to having their responses being included in the data analysis. The participants also confirmed that they did not need any clarification regarding the informal learning resources mentioned in the questionnaire. The two focus groups were held within the same conferences in which the survey questionnaires were collected. Focus group participants chose to attend and had selected the focus group from a range of workshop options that were offered at the conferences.

3.5 Data analysis

Once the questionnaire data were collected these were uploaded to the Statistical Package for Social Science (SPSS) system as de-identified input. The focus group discussions were recorded and transcribed. The data from both focus groups were aggregated for analysis purposes. An inductive thematic analysis of the data was guided by the research questions (Patton, 2015). This was an iterative process where participant statements were discussed between the researcher and the research supervisors and contextualised by the responses to the questionnaire. This discussion continued until a consensus was reached regarding our interpretation of individual statements. This method was similar to many of those

employed by recent studies in the field of teacher professional development (Campbell, 2017; DeLuca et al., 2017; Durksen et al., 2017; Keiler, 2018; Lindqvist et al., 2017). DeLuca et al. (2017) surveyed teachers using written questionnaires and conducted focus groups with teachers to examine their perspectives into professional learning through collaborative inquiry. Data collected from the focus groups were collapsed for analysis purposes, and they used inductive thematic analysis which was guided by their research questions. The researchers discussed quotations and, after having reached a consensus, they generated thematic categories based on the coded data

Answers to the research questions were provided through the analysis of the survey questionnaires and focus group discussions, as described below.

Question 1 analysis. The questionnaire data were aggregated and the mean frequency of use rating for each resource was calculated and presented in a frequency chart.

Question 2 analysis. The combined data from the questionnaire and the focus groups were read multiple times. Through a process of thematic analysis, categories of purposes emerged. The various responses were allocated into categories. When a single response fell into more than one category, the categories were modified. This iterative process continued until exclusive categories were formed, in which each response could only fit into one category of purpose.

Question 3 analysis. The data collected through questionnaires were analysed to identify if there were differences in the frequency of accessing informal learning resources, compared to the number of years teaching experience. An analysis of variance (ANOVA) was conducted to compare the mean frequency of use rating for each resource to the number of years teaching experience. *Post-hoc* analyses were conducted to identify where these differences occurred.

A common choice of analytical test for determining if there are statistically significant differences between the means of groups is an analysis of variance (ANOVA) test (Scheffe, 1999). In the current study a Welch ANOVA test was performed, where the independent variable is the participants number of years'

teaching experience and the dependant variable is the mean frequency of use rating. A Welch ANOVA test was performed in preference to a one-way ANOVA test as the former test does not assume homogeneity of variance of the dependent variable, and is thus an appropriate choice for analysis of the variance between the groups of participants with different number of years teaching experience (De Winter, 2013).

Questionnaire participants indicated their number of years teaching experience. They selected from the categories: *>1 year*, *2-5 years*, *6-10 years*, *11-15 years*, *16-20 years*, *21-30 years* and *>31 years*. Given that the number in each of these groups did not all meet the criterion of 15 participants required to conduct a Welch ANOVA test for non-normally distributed data, the participants' responses were combined into three revised groups. The teachers with between 1 and 5 years of teaching experience were grouped as *early career teachers.* The teachers with between 6 and 15 years of teaching experience were categorised as *mid-career teachers* and the teachers with 16 years or more teaching experience were categorised as *advanced career teachers.* Table 3.3 presents these categories and the number of participants in each career stage.

Table 3.3

Number of Participants in Each Career Stage (n = 91)

Career Stage	Number of Years Teaching	Number of Teachers
Early career	1-5	35
Mid-career	6-15	30
Advanced career	16+	26

Question 4 analysis. The combined data from the questionnaire and the focus groups were read multiple times. Thematic analyses of the participants' qualitative responses were used to identify individual categories of informal learning resource.

3.6 Validity, reliability and trustworthiness

As a mixed-method study, both quantitative and qualitative data were collected. The results of the quantitative data analysis are discussed in terms of *validity* and *reliability*. *Validity* is concerned with whether the research is evaluating what it purports to evaluate (Zohrabi, 2013); and *reliability* deals with the

consistency of the results obtained from a piece of research (Heale & Twycross, 2015, p. 66). The results of the qualitative data analysis are discussed in terms of *trustworthiness*, which relates to the extent to which the researcher's interpretations are well-contextualized and may be trusted (Elo et al., 2014; Lincoln & Guba, 1985). Being a mixed-methods study, all three are considered in what follows.

3.6.1 Validity

Validity is defined as the ability of a quantitative instrument to measure the attributes of the construct under study (Mitchell & Jolley, 2012). The *validity* of research includes two domains: *internal* and *external* validity.

Internal validity for a questionnaire refers to the extent to which the items on a questionnaire unambiguously measure what they are intended to measure which allows for connecting causes to affects (Patino & Ferreira, 2018). In this study, *internal validity* of the questionnaire was established through *face validity* which is the appropriateness, sensibility, or relevance of a questionnaire and its items. It is the degree to which participants view the questionnaire items to be relevant to the context in which the questionnaire is being administered (Holden, 2010). Questionnaires where the purpose is clear, even to naïve respondents, are said to have high *face validity* (Nevo, 1985). While this is not an objective measurement of *internal validity*, the respondents were clear regarding the extent to which items on the questionnaire were actually measuring their real-world frequency of use of the various informal learning resources. On completion of the questionnaire the researcher spoke with each participant to elicit their perception of the *face validity* of the questionnaire including the appropriateness, sensibility, and relevance of the questionnaire and its items. *Face validity* applies only to the closed questions of the questionnaire and does not apply to the qualitative aspects of the questionnaire such as the participants' purposes of accessing each informal learning resource. *Face validity* also does not apply to the qualitative data collected in the focus group discussions.

External validity refers to how the results of this study can be generalized to the population of science teachers outside of those who directly participated in the study (Onwuegbuzie, 2000). The results may not be generalizable for the whole population of secondary school science teachers in the state of Victoria, Australia,

but rather skewed towards the population of secondary school science teachers who attended the conferences and were willing to participate in the study. The current study sample is representative of the population with a precision of ±10.12% at a confidence level of 95% as discussed in Section 3.4.2.

3.6.2 Reliability

Reliability refers to the ability of an instrument to measure an attribute consistently (DeVon et al., 2007). To evaluate the reliability of the questionnaire, the participants' responses were analysed through inter-item correlation. In inter-item correlation analysis, the participants' responses to each item are correlated with their responses to every other item on the questionnaire to assess whether individual questions on a questionnaire give consistent, appropriate results (De Vaus & de Vaus, 2013). The Cronbach's *alpha* coefficient, α, is a statistical test commonly used to demonstrate that tests and scales that have been constructed or adopted for research projects are fit for purpose and it is regularly applied in studies in science education as a measure of *reliability* (Taber, 2018). Cronbach's *alpha* for this questionnaire was calculated and found to be α = 0.894. Gliem and Gliem (2003) suggest that a value of α = 0.8 is a reasonable goal for a Cronbach's *alpha* coefficient to indicate good internal consistency. The α = 0.894 for the questionnaire in the current study suggests that the questionnaire and the scale that it used have a high level of consistency and were fit for their purpose.

3.6.3 Trustworthiness

Trustworthiness in qualitative research methods is framed as a parallel criterion to the quantitative criteria of *validity* and *reliability*, all of which are benchmarks for rigor in data collection and analysis (Lincoln et al., 2011). These parallel criteria are intended to loosely achieve the same purposes as *internal validity*, *external validity*, *reliability*, and *objectivity* in quantitative research (Morrow, 2005). For qualitative research to be considered trustworthy it is necessary to establish that the research study's findings are credible, transferable, confirmable, and dependable (Lincoln & Guba, 1985). Framed in terms of parallel criteria, *credibility* in qualitative research is said to correspond to *internal validity* in quantitative approaches, *transferability* to *external validity* or *generalizability*, *dependability* to r*eliability*, and *confirmability* to *objectivity* (Morrow, 2005). The

trustworthiness of content analysis results depends on the availability of rich, appropriate, and saturated data (Elo et al., 2014).

Credibility refers to how confident the researcher is in the truth of the research study's findings (Shenton, 2004). *Credibility* can be increased by triangulating the results from different research methods (Guba, 1981). In social research the term *triangulation* is used to refer to the observation of the research issue from at least two different points (Flick, 2004). This study uses two sources of data: questionnaires and focus groups. The use of different forms of data collection compensates for their individual limitations and exploits their respective benefits. In the case of this study, the application of triangulation applies only to the instruments. As discussed earlier, participants in the focus groups, had also completed the questionnaire.

A qualitative study is *credible* when it presents accurate descriptions or interpretation of human experience that people who also share that experience would immediately recognise (Sandelowski, 1986). During the focus group discussions, the participants first discussed topics in sub-groups. Following these discussions, the sub-groups combined to discuss the same topic in a larger group in order to identify similarities and differences in the sub-group responses. This offered the participants an opportunity to reflect on their responses and to raise questions regarding the perceived truthfulness of both their own statements and the statements of other participants during the focus group discussion. Shenton (2004) suggests that researcher familiarity with the culture of the participants can also increase the *credibility* of qualitative results. In the case of the current study the researcher facilitating the focus groups, is also a secondary school science teacher in the state of Victoria, Australia, and is thus familiar with the professional culture of the participants.

Transferability considers how the researcher demonstrates that the research study's findings are applicable to other contexts. The findings of a qualitative project are usually specific to a particular situation or group of people. For this reason, it is usually not possible to demonstrate that the findings and conclusions are applicable to other situations and populations (Shenton, 2004). *Transferability* of a study can be improved by comparison of the study's participant sample to

demographic data (Krefting, 1991). A comparison of the participants in the current study to the population of teachers in Australia in Section 3.4.2 indicated similarities in terms of age profile and gender thereby increasing the transferability of the findings of the current study to the population of science teachers in Victoria.

Confirmability discusses the degree of neutrality in the research study's findings. This involves ensuring that researcher bias does not skew the interpretation of participants' responses to fit a certain narrative (Shenton, 2004). Being a secondary school science teacher in Victoria, Australia, it was necessary for the researcher to be aware of these potential investigator biases. Triangulation of data can be used to reduce the effect of investigator bias, and in the current study written comments from the questionnaires were compared with comments from the focus group discussions to identify potentially different interpretations of the data. As a means to this end the focus group discussions were transcribed to allow for multiple re-readings of the data. An inductive approach was used to identify patterns in the data by means of thematic analysis. The inductive approach requires that the patterns, themes, and categories of analysis emerge out of the data rather than being imposed on the data before analysis (Patton, 1980). The *confirmability* criterion was addressed in this study in the analysis of the categories of informal resources used by teachers. *Posteriori* modifications were made to the *a priori* categories when the expected categorisation was not supported by the collected data.

Finally, *dependability* is the extent to which a study can be repeated by other researchers and that the findings will be consistent (Shenton, 2004). The processes by which the data were collected have been fully described, and this would enable a future researcher to repeat the work. While other researchers may not be able to attend the same conferences and collect data from necessarily the same people, the methods used in the study can still be repeated. The questionnaires are replicable as an identical questionnaire can be reproduced and distributed (see Appendix A). The focus group protocol and the A3 stimulus sheet provided in both focus groups was the same and could be replicated (see Appendix B). Discussions are not replicable as they were semi-structured and the discussions which took place were partly directed by the comments of the participants.

In developing the research instruments the *internal validity* of these was established though *face validity* and *external validity* and *generalizability* were established by using an appropriate sample size. The *reliability* of the questionnaire was measured using inter-item correlation and ensuring that the Cronbach *alpha* coefficient indicated good internal consistency. The *trustworthiness* of the results was increased by the position of the researcher as a secondary school science teacher. Threats of potential biases were primarily addressed through triangulation of data from the questionnaire and the focus groups.

3.7 Ethics

Ethics approval was obtained from the University Ethics Committee (ID: HRE16-243). This is a low-risk study as all participants are adults and the target group is representative of the normative demographic of secondary school science teachers who are not considered to be marginalised or vulnerable. All participants were provided with an information sheet prior to participation in the focus groups and responding to the questionnaire. They were asked to sign a consent form indicating their willingness to take part in the study.

To maintain the confidentiality of the participants, no details regarding the conferences in which the data were collected, including data collection dates, location and other conference details have been given.

All names were de-identified in this study. For the questionnaire responses, once the data were collected these were uploaded to the SPSS system as de-identified input. These responses were stored as numbered values from 001 to 091 and are referred to in this study as ‘Questionnaire Participant’ followed by their number, such as ‘QP019’. The number assigned to each participant reflects only the random order in which the data from each questionnaire was uploaded to SPSS.

The focus groups were recorded (using a digital voice recorder) with the permission of the participants and participants were reminded that they could discontinue their participation in the research at any time, with no need to explain or justify their withdrawal. Unlike the questionnaire data, it was not possible to

preserve the full anonymity of the participants in the focus groups. However, the names of the participants were de-identified in the transcripts and other written materials. While the names of the participants were known to the researcher during the collection of the data these names were not preserved in any way in the transcripts. References to the focus group participants in this thesis designate only whether the participant was a member of the biology focus group or the chemistry focus group. Further designation refers to the sub-group that the participant joined. For example, focus group member CG2A indicates that the person was a member of the chemistry focus group and was in the sub-group 2. This differentiates that person from focus group participant CG2C who was a member of the same chemistry sub-group and CG1C who was a member of another sub-group in the chemistry focus group.

The data gathered for the duration of the project are stored in a password-protected computer and manually locked filing cabinet.

4. RESULTS

Chapter Overview

The results are presented in accordance with the following sequence of the research questions: Question 4 is addressed first. The question examines the gap between the questionnaire's *a priori* and *posteriori* categories and their constituents. Once the *posteriori* categories are established, further analysis of Questions 1-3 is based on these categories. The analysis of Question 4 is followed by presenting the analysis results related to the frequency in which secondary school science teachers access informal learning resources; their purposes in accessing these resources; and finally, examination of the relation between years of teaching and frequency of use of informal resources. The chapter is concluded by a summary of the main findings.

4.1 *A priori* and *posteriori* categories and constituents

A priori categories and constituents of informal learning were developed and presented in the questionnaire completed by the participants. Table 4.1 presents the five categories and their constituents.

Table 4.1

A priori Informal Learning Resources Categories and their Constituents

Interactive Media	Non-interactive Media	Interpersonal Communications	Exhibitory and Experiential Learning	Printed Media
Twitter	Google (and other search engines)	Conversations with colleagues	Zoos	Books
Facebook	Television programs	Conversations with friends and family	Museums	Newsletters
Skype	YouTube (and other video platforms)	Seeking expert advice	Aquaria	Journal articles
Online courses	Online teaching resource banks (e.g. GTAC, TES)		Exhibitions	Science magazines
Snapchat	Online curriculum		Outdoor activities	
WhatsApp			Community and social events	
Google Docs (and other file sharing platforms)			Citizen science	
Instagram			Public lectures	
Blogs			Clubs and societies	
Discussion forums (e.g. talkphysics)			Non-accredited conferences	

An analysis of the collected data through the questionnaires and the focus groups, revealed various gaps between the above categories and the participants' responses. In order to align the categories with the participants' responses, there was a need to revise the *a priori* categories and form *posteriori* categories. The gaps and the revisions are discussed in what follows.

4.1.1 Gap 1: Printed materials compared to digital materials

The data analysis revealed overlap between the categories *printed media* and *non-interactive media*. There was a strong indication that the resources presented within *printed media* are accessible online, thus eliminating the need for the *printed media* category. The data provided multiple evidence supporting this finding. A participant in one of the focus groups felt that it was irrelevant whether information was accessed online or in print, asking: 'Printed information? Doesn't really matter, because everything is now available online. How do you make a

difference between journal article online and printed?' (CG2A). Another participant wrote: '[I] use online resources rather than printed material' (QP019).

In the focus group discussions, it was noticeable that participants used the words *book* and *e-book* interchangeably. For example, CG1A found that 'with the e-book, it is really good, a lot of the books have videos and things like that'. While this participant started speaking about an e-book, they then used the term 'book' to describe the same resource. In another focus group, BG1A stated that: 'all of our textbooks are online'. Another participant wrote 'now [I] use e-books more' (QP042).

The teachers expressed similar experiences with regard to science magazines, journal articles and newsletters. One teacher stated: 'science magazines, journal articles, we don't really [use these] unless we purchase it online' (BG1A). Participant QP002 gave their purpose in accessing newsletters as: 'e-newsletters, quick scan only'. Statements such as these suggest that there is no basis for separating printed and digital resources into different categories.

As an outcome of the data analysis, the two categories of *non-interactive media resources* and *printed media* have been merged as *non-interactive media resources*.

4.1.2 Gap 2: Google Docs as a formal resource

The first category, *interactive media resources*, originally included Google Docs (and other real-time, file-sharing platforms), Twitter, Facebook, Skype, online courses, Snapchat, WhatsApp, Instagram, blogs and discussion forums. During the process of analysis, questions were raised regarding the appropriateness of considering Google Docs as an informal resource. The results analysis revealed that the mean frequency of use rating for Google Docs (M = 2.81, SD = 1.43), deviates substantially from the other resources in the category. This mean frequency of use rating is approximately twice that of the other interactive media resources. The mean frequency of use rating for all other informal learning resources in this category, when Google Docs is removed, is M = 1.41, SD = 0.78. This deviation raised a concern as to whether Google Docs is an informal resource.

The definition of informal science teachers' PD used in this study emphasizes the aspect of free choice in accessing informal PD resources. The evidence suggests that Google Docs is used at times by free choice and, at other times, not by free choice. Qualitative analysis of the written explanations revealed that, for many participants, using Google Docs is a school requirement, making this resource a formal rather than informal learning resource. While in other cases this resource is used by free choice. The following quotes taken from the questionnaires, demonstrate this duality. Participants QP088 and QP017 described how their school necessitates using Google Docs: 'Our school is a Google school' (QP088); and 'Google apps extensively used at school' (QP017).

Free choice usage was described as follows:

> I worked with a guy…we are sharing resources. This year we have collected the e-mails for all those who are teaching science in our system, and we put them together and created a folder in Google Drive, so people are just putting in there…this is how I did my course program…this is how I approached this topic (CG2B)

As a consequence of this duality, Google Docs was omitted from the data analysis of Questions 1 and 3. The first question required a frequency of use rating analysis of the teachers' uses of informal resources. The third question required an analysis of variance to determine the relation between the number of years of teaching experience and the frequency at which resources were used. For both purposes it was essential to exclude ambiguous variables. Since it was not possible to distinguish between the frequency at which Google Docs is used as a formal resource and the frequency at which it is used informally, it was excluded from both analyses. This was not the case in regard to the analysis of Research Question 2. The question asks: What are the teachers' purposes when accessing informal learning resources? The participants' descriptions of their purposes of use provided a clear indication as to whether the uses may be regarded as formal or informal. Only responses that related to informal uses were included in the analysis of the results relating to Question 2.

4.1.3 Posteriori categories of informal learning resources

Having addressed the gaps in the *a priori* categories of informal learning resources, the *posteriori* categories are described and justified in what follows.

These *posteriori* categories are *interactive media*, *non-interactive media*, *interpersonal communications* and *exhibitory and experiential resources.* The *posteriori* informal learning categories and their constituents are shown in Table 4.2. In this revised table, the category of *printed materials* has been merged with that of *non-interactive media.* Google Docs remains in the *interactive media* category, as its use is analysed to answer Research Question 2, the teachers' purposes in accessing informal learning resources. Google Docs is not included in the analysis of Research Questions 1 and 3 which analysed the use of informal learning resource only.

Table 4.2

Posteriori Informal Learning Categories and their Constituents

Interactive Media	Non-interactive Media	Interpersonal Communications	Exhibitory and Experiential Learning
Twitter	Google (and other search engines)	Conversations with colleagues	Zoos
Facebook	Television programs	Conversations with friends and family	Museums
Skype	YouTube (and other video platforms)	Seeking expert advice	Aquaria
Online courses	Online teaching resource banks (e.g. GTAC, TES)		Exhibitions
Snapchat	Online curriculum		Outdoor activities
WhatsApp	Books		Community and social events
Google Docs (as an informal resource)	Newsletters		Citizen science
Instagram	Journal articles		Public lectures
Blogs	Science magazines		Clubs and societies
Discussion forums (e.g. talkphysics)			Non-accredited conferences

Interactive media

The term *interactive media* has been applied to a variety of media, but its primary communication quality is the responsiveness and interrelationship of the messages that communicators can exchange (Walther, 2017). Interactive media include resources where users can access information, write replies or contribute their own content (Rice & Williams, 1984). These resources are dynamic, with content that continually changes (Jensen, 1998; Xu & Sundar, 2016). The user of

the resource can be both a consumer and a provider of new materials, referred to in digital media research as a *prosumer* (McLoughlin & Lee, 2008).

Non-interactive media

The term *non-interactive media* refers to using media content without producing, uploading or sharing one's own contribution to a specific platform (Walther, 2017). Within digital media studies, uses of YouTube and Google entail engaging these platforms according to their own, different affordances (Rogers, 2017). Affordances of the platform YouTube enables content creation and dissemination. It is essentially a *database* where users upload audio-visual clips or videos and allows for easy accessibility through its search function (Lange, 2007; Simonsen, 2011). The affordances of Google enable users to search for content using individual words, terms, sentences or questions. For the purpose of this study, the platforms YouTube and Google are referred to as *non-interactive* because participants in the study tended to search for and consult resources on these platforms but not contribute content to these.

Digital resources may differ from printed materials, with benefits that include: text searching, navigation, cross-references, hypertext links, bookmarks and annotations as well as allow functions such as printing, downloading, storing and posting by e-mail (Vassiliou & Rowley, 2008). However, in this study, digital resources were mainly viewed by the study participants as an electronic/digital version of the traditional printed book made accessible with the help of appropriate hardware and software. This is similar to the difficulties found in the literature with defining exactly what constitutes an e-book (Vassiliou & Rowley, 2008). The current study treats YouTube, Google and digital resources as *non-interactive resources.* The key feature of *non-interactive resources* is the ways in which users can create, store, deliver and access digital content according to the meaning and value they attribute to digital resources (Cope & Kalantzis, 2009).

Interpersonal communication

Interpersonal communications are transactions that allow people to reflect and build personal knowledge of one another and create shared meanings (Wood, 2015, p. 21). When a person engages in interpersonal communications, they do so under the assumption that the person or persons with whom they are

communicating will engage with the communication actively rather than passively. An example of indirect, passive communications is posting to a Facebook group. The persons who post to such groups or forums may not necessarily intend to engage in direct dialogue with one or more people but rather to share information which may or may not be picked up by others. In contrast, interactive interpersonal communications are processes in which listeners give feedback in response to a message and that communicators create and interpret messages within their personal fields of experience (Wood, 2015, p. 17). These may also take the form of communities of practice (Wenger, 2011). For the present study *interpersonal communication* includes direct communication with individuals or groups of individuals through face-to-face conversations, landline phone, mobile phone or voice over internet protocol (VOIP), computer-mediated communications such an e-mail or instant messaging (IM) for the purpose of sharing information science content, and providing information about resources (Cheng et al., 2017; Madianou & Miller, 2013).

The increasing variety of affordances offered by social media platforms causes them to become more complicated to categorise (Vermeulen, Vandebosch, & Heirman, 2018). Some of the interactive resources in this study such as Skype, WhatsApp, Instagram, Twitter and Facebook offer direct instant messaging and one-to-one calls by their users and these also offer group communications. For the purposes of this study, the medium used for interpersonal communications was not specified, offering the participants an opportunity to report on their frequency of accessing interpersonal communications without being limited by their mode of interaction (Qiao et al., 2018).

Exhibitory and experiential resources

The *exhibitory and experiential resources* category draws upon literature relating to experiential learning. Exhibitory learning has been used to describe out-of-school learning such as authentic experiences using real objects, phenomena, or animals in science-based facilities, environments and institutions. These include: science museums, zoos, aquaria, science outreach centres, planetariums, and botanical gardens (Bell et al., 2009; Phillips et al., 2007). Experiential learning is ‘participative, interactive, and applied. It allows contact with the environment, and

exposure to processes that are highly variable and uncertain (Gentry, 1990, p. 20; Shaby et al., 2019). Furthermore, experiential learning relates to situations where participants could be a member of a group involved in science-related activities such as a club or society, any science-related outdoor activity, or be a part of a citizen science research project.

4.2 Informal learning resources that are accessed by secondary school science teachers

The informal learning resources were analysed in accordance with the four categories: (i) *interactive media*; (ii) *non-interactive media*; (iii) *interpersonal communications*; and (iv) *exhibitory and experiential resources*. Data sources for addressing this question included questionnaire responses (n = 91) and two focus group discussion transcripts (n = 6 and n = 11).

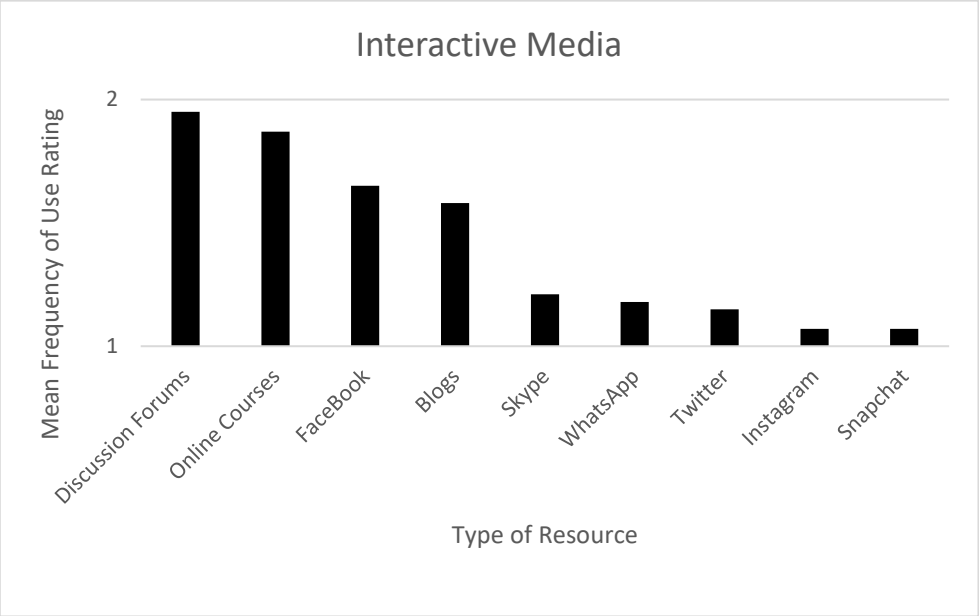
4.2.1 Interactive media

All of the resources in this category were rated below 2 on the Likert scale for the mean frequency of use rating. On this scale, 2 corresponds to *rarely used* (i.e. 1-10 times in a typical month). This indicates that the secondary school science teachers do not frequently use interactive media to inform their teaching and professionality.

Within this low mean rating range, there appears to be two groups. The first ranges between a mean rating of 1.50 to 2.00; and the second between 1.00 to 1.50. The higher end, close to 2.00 (*rarely used*), includes discussion forums, online courses, Facebook and blogs. The lower end, close to 1.00 (*never used*), includes Skype, WhatsApp, Twitter, Instagram and Snapchat. All five least-accessed interactive resources can be categorised as *social media platforms*. Figure 4.1 presents results for the *interactive media* category. The mean frequency of use rating of each resource type is presented.

Figure 4.1

Mean frequency of use rating of interactive media resources, by resource type



Fifty of the 91 questionnaire participants stated that they participated in online courses. The mean frequency of use rating for *online courses* is *M* = 1.81, *SD* = 1.01. When discussing *online courses*, a participant in the biology focus group stated that 'if you are just doing it for your own knowledge... the ones I was looking at, they are self-contained, so you can start whenever you want and finish whenever you want' (BG1A). Participants in the chemistry focus group also discussed participating in *online courses*. Participant CG2B suggested to other participants to use 'online courses, from Harvard Uni. Arranged for different subjects'. Participant CG2A commented that 'I have done an online course from Swinburne…which was very handy because it was an entirely online based course'. Teachers reflected on the quality of the *online courses*. Participant BG1C found that 'Khan Academy is really poor, because you have that really poor cross haired dot thing and the guy is trying to write, and it is really horrible.'

In the focus group discussions, social media such as Facebook and Twitter were described as being useful up to a point. It was suggested that collaborative groups needed to be small in number and specific in purpose otherwise they tended to result in wasted time and circular discussions that led to little progress for

the participants. This was described by participants in the biology focus group. Participant BG2C said that ‘I have used Twitter, I used it for a while. It was useful for a bit but became less useful over time’. Participant BG3D commented that ‘Facebook is most effective if you are in a very specific discussion forum group’. Participant BG3D also thought that ‘if you want to use Facebook effectively it’s about finding groups that are just focused on biology or what you want to get information on’. This finding confirms previous findings showing that teachers prefer to participate in small Facebook groups, rather than large ones (Lantz-Andersson et al., 2017). Similarly, these studies have shown that large groups are unable to provide a sense of support, collegiality and effective feedback, which meet teachers’ expectations (Clarà et al., 2017; Kelly & Antonio, 2016; Lin et al., 2008).

The mean frequency of use of rating for Twitter is $M = 1.15$, $SD = 0.63$. Of the 91 participants, only 6 participants indicated they used Twitter. The remaining 85 participants rated it as 1 on the Likert scale. On this scale 1 corresponds to *never used* (i.e. zero times in a typical month). Some of the questionnaire participants provided specific reasons for using Twitter. For example, participant QP012 wrote that they read ‘Twitter blogs on education resources links’ and participant QP049 used Twitter ‘to gain knowledge on a global scale’. Participant QP052 wanted to ‘see what others are doing’.

Participants did not feel it necessary to justify their lack of use of other media in this category but felt compelled to excuse their low frequency of use of Twitter. For example, participant QP036 wrote that they are ‘thinking of moving into this space shortly’. This may reflect teachers’ attitudes that Twitter seems useful but does not meet their immediate PD needs. One participant said that ‘I’m not on Twitter, but I have heard of some really good ways to use it, like following leaders in education. And that is up-to-date information that you can access. I just can’t be bothered to use it’ (BG3D).

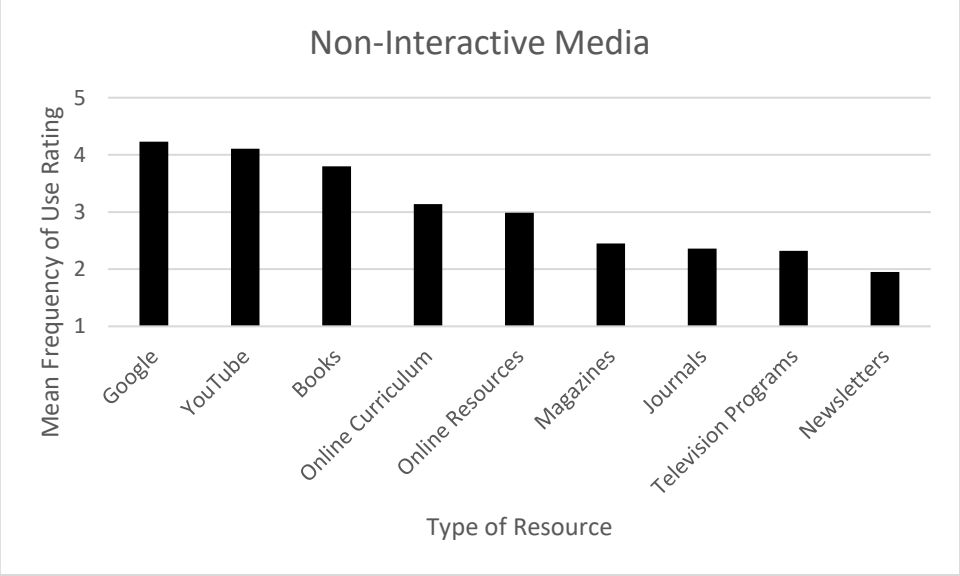
Overall, *interactive media resources* have a low frequency of use rating when compared to the much higher frequency of use rating for *non-interactive media resources*.

4.2.2 Non-interactive media

The resources in this category appear to fall into two groups according to their ranking. The five most highly rated resources all provide tailored information. Tailored information is information that is delivered with high specificity to the user's needs and is available at a time when the user needs the information. The first group, which presents high rankings, and includes: Google (*M* = 4.23, *SD* = 1.00), YouTube (*M* = 4.11, *SD* = 0.97), books (*M* = 3.80, *SD* = 1.16), online curriculum (*M* = 3.14, *SD* = 1.33) and online resources (*M* = 2.99, *SD* = 1.34). The second group presents medium ranking and includes: magazines (*M* = 2.45, *SD* = 0.95), journals (*M* = 2.36, *SD* = 1.01), television programs (*M* = 2.32, *SD* = 0.92), and newsletters (*M* = 1.95, *SD* = 0.94). Figure 4.2 presents results for the *non-interactive media* category. The means of the frequency of use ratings are presented in terms of the resource types.

Figure 4.2

The mean frequency of use ratings of non-interactive media, by resource type



Of the 91 participants, 88 used *Google (and other search engines)* as an informal learning resource. An affordance of Google and similar platforms is the search function, which provides users with an opportunity to find the specific information they need, when they need it (Zhang & West, 2020). This facility to find highly specific information 'just in time' appears to be an important criterion for

teachers when choosing which informal learning resource to access (Wilson, 2013). Search engines such as Google allow the user to write a full question for which the platform searches to find the most appropriate resulting matches.

Questionnaire participants access *YouTube* with a high frequency, *M* = 4.11, *SD* = 0.97. Participants wrote about using YouTube 'to get short and relevant explanations, animations' (QP044). The participants in the focus groups also frequently mentioned YouTube as a good resource for videos, animations or summaries. Some specific channels on YouTube were mentioned in the focus group discussions, such as *Bozeman* and *Crash Course*. These YouTube channels provide explanations and animations on a range of science topics particularly aimed at secondary school science curricula.

The questionnaire participants' written responses provide further insights regarding the teachers use of the various resources in this category. *Books* are a popular informal learning resource. The mean frequency of use rating for books (*M* = 3.80, *SD* = 1.16) exceeded that of online resources (*M* = 3.10, *SD* = 1.33). Books, particularly textbooks, are regarded as reliable resources for quality information relevant to the curriculum. Participant QP049 wrote that books were 'my main sources, as textbooks are the most up to date with the curriculum'. These books may be part of the formal curriculum as prescribed textbooks, but participants in the current study describe using them in ways that can be regarded as informal learning, such as Participant QP006 who wrote that he/she uses books for 'checking on topics I haven't taught at all or for a while'. This participant uses books to either self-teach content knowledge or expand their existing content knowledge through informal learning.

The Australian Curriculum, Assessment and Reporting Authority (ACARA) is responsible for the development of the Foundation to Year 10 curriculum in Australia (ACARA, 2022). In Victoria, the Foundation to Year 10 curriculum is provided by the Victorian Curriculum And Assessment Authority (VCAA) and incorporates the Australian Curriculum while reflecting Victorian priorities and standards (VCAA, 2020). The VCAA provides 'teaching and learning plans, information on curriculum planning and assessment, curriculum area-specific advice, and professional learning opportunities' (VCAA, 2020). For the participants

in the current study, the informal learning resource *online curriculum* was not limited to curriculum materials from the state of Victoria (VCAA, 2020) or the Australian national curriculum (ACARA, 2022). Participant QP011 wrote that they accessed online 'curriculum from others, including curriculum from other states (e.g. QLD) used as comparison for curriculum design'. Participant QP008 wrote that they access 'Atlas-school curriculum database'. Atlas is an online planning, assessment and reporting platform for independent schools world-wide (Atlas, 2021).

In the questionnaire, some of the participants specified that they used the online curriculum materials produced by private education resource providers including Edrolo, Education Perfect, and Study Clicks. These providers offer a range of teaching materials from video clips to online tests which are geared towards the curriculum. While it may be argued that these resources should be regarded as either an online course or online resource rather than online curriculum, some of the questionnaire participants specified that they used Edrolo as an online curriculum, such as QP0039 who wrote that they have an 'intranet setup and Edrolo'.

As an *online resource*, private providers such as Edrolo, could be considered as being formal learning resources for students. A participant in the biology focus group, however, stated that such resources could equally be useful for teachers looking to inform their teaching and professionality, even though the resource has been designed primarily for student learning.

> I'll give you a tip also, because if you haven't taught and you want to step up to take year 12's, do the Edrolo course, because they will help you… and if you go through the Edrolo you will be able to add little things, to your own knowledge base, that would be my advice. I mean, I did the same, I taught maths methods at year 12 and I learned a few things. I mean I had my knowledge to teaching mathematics but just to make sure, all the little tips and tricks, and how to's, it's a good thing to do (BG1C)

It appears that resources from providers such as Edrolo are being adopted in some schools as a formal part of the curriculum, but some teachers are informally using it to self-teach content and to expand their subject content knowledge. The previous comment from BG1C reflects its informal use; the same participant also describes

Edrolo's use as a formal resource stating that 'our school is starting to use the Edrolo resources. The kids tap in online, and as part of the interactivity the kids can answer questions and assess their knowledge and that comes back to the teacher about the class'.

One particularly popular *online resource* is the Gene Technology Access Centre (GTAC), which was mentioned by eight of the 91 questionnaire participants and was discussed at the biology teacher's focus group as a particularly useful resource for accessing classroom-ready teaching resources. Participant BG2A commented **'**DNA interactive DVD from GTAC, really good animations'. Another online resource, Pinterest, was briefly discussed by one participant. Participant BG1A described using 'Pinterest, sometimes. Because I teach 7 to 10 as well, and sometimes I, and my lab tech as well, we will go on Pinterest and look for some activities…and sometimes we will just be lost for hours. Just looking and looking or find nothing that relates'. One of the questionnaire participants also wrote about their use of Pinterest: 'Pinterest: finding new hands-on activities for students' (QP090).

The second group of resources in the category non-interactive informal learning resources reflecting medium frequency of use includes, *magazines, journals, television programs* and *newsletters*. By comparison to the first group representing the more frequently accessed resources, this second group does not appear to be as well-positioned to offer tailored information. The primary difference between the affordances of *YouTube* and *television programs* appears to be that the user can access a video on *YouTube* at any time, rather than at fixed times which may be the case for regular broadcast television. Though this may be changing with the increasing availability of broadcast television with on-demand, web-based media players, the situation remains that there is much less content choice available through traditional television resources. Accessing videos on *YouTube* also allows the user an opportunity to tailor their viewing to their specific needs by using the search function, and immediately follow up the video they are watching with other related videos or to search for something completely different.

The lowest frequency of use rating in the non-interactive category is *newsletters*. The primary limitation of *newsletters* appears to be that the recipient is

being provided with general information that the newsletter writers believe to be important, not necessarily what the recipient believes to be important or what they, as individuals, feel they need to know. It lacks both specificity of information and timing. *Newsletters* appear to be viewed by the participants as an outdated way to access information, which would not necessarily add any value for the person accessing it. Participant QP003 wrote that they look at 'e-newsletters, quick scan only'. The large difference observed between *newsletters* (M = 1.95, SD = 0.94) and Google (M = 4.23, SD = 1.00) may be due to the active decision of the user to seek information.

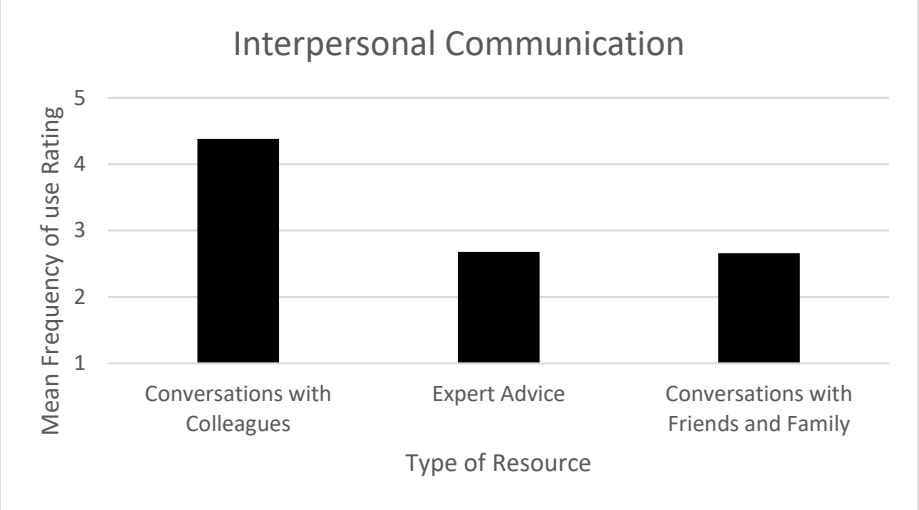
The participants found particular value in non-interactive resources which allows them to access information that answers their specific questions. There is also strong evidence of participants using resources that are aimed at secondary school students as sources of informal learning for the teachers. This includes school textbooks, YouTube and resources such as Edrolo. The participants appear to prioritise resources that allow them to self-teach content to aid their teaching of students in secondary school.

4.2.3 Interpersonal communication

All resources categorised as *interpersonal communications* in the questionnaire yielded a mean frequency of use rating above 2 on the Likert scale. On the Likert scale 2 corresponds to *rarely used* (i.e. 1-10 times in a typical month). Figure 4.3 presents the mean frequency of use ratings for *interpersonal communications* by resource type.

Figure 4.3

The mean frequency of use ratings for interpersonal communication, by resource type



All 91 questionnaire participants stated that they used *conversations with colleagues* as an informal learning resource. The single, most frequently accessed resource of informal learning across all categories is *conversations with colleagues* (*M* = 4.38, *SD* = 0.85). On the Likert scale 4 corresponds to *frequently used* (i.e. 21-30 times in a typical month) and 5 corresponds to *very frequently used* (i.e. >30 times in a typical month). This rating is even higher than the rating of Google, which was the highest among electronic resources. This important finding suggests that *interactive media* has not gained precedence over *interpersonal communication* and it is not a substitute for direct unmediated communication. The secondary school science teachers clearly gain a significant portion of their informal learning from their colleagues and appreciate face-to-face communication.

The participants in the focus groups indicated that *conversations with colleagues* helped them to choose which teaching resources to use. Participant BG3A in the biology focus group explained that conversing with colleagues helps ‘break down that noise. Because you can just spend hours looking for resources for one class’. Participants also emphasized the importance of *conversations with colleagues* in their written questionnaire responses. The various responses include: ‘Learning from more knowledgeable people’ (Participant QP003); and ‘Tapping into other people's expertise’ (Participant QP009). In some instances, participants

mentioned a collaborative approach to teaching content and specific topics. For example: ‘Share ideas of assessment tasks, experiments, bounce ideas off’ (Participant QP029); and ‘Sharing of resources used in classes’ (Participant QP036). It is clear from the results that the secondary school science teachers value time to collaborate with their colleagues. However, Participant QP049 noted that opportunities might be limited ‘depending on the time given from leadership team at school’.

Written responses to the questionnaire indicated that the participants accessed *expert advice* for a variety of purposes. Participant QP019 wanted to get ‘information needed for new experiments/equipment’ (QP019). Participant QP065’s purpose was to ‘confirm quality and accuracy of teaching programs’ and participant QP008 accessed expert advice ‘to get ideas/validate’.

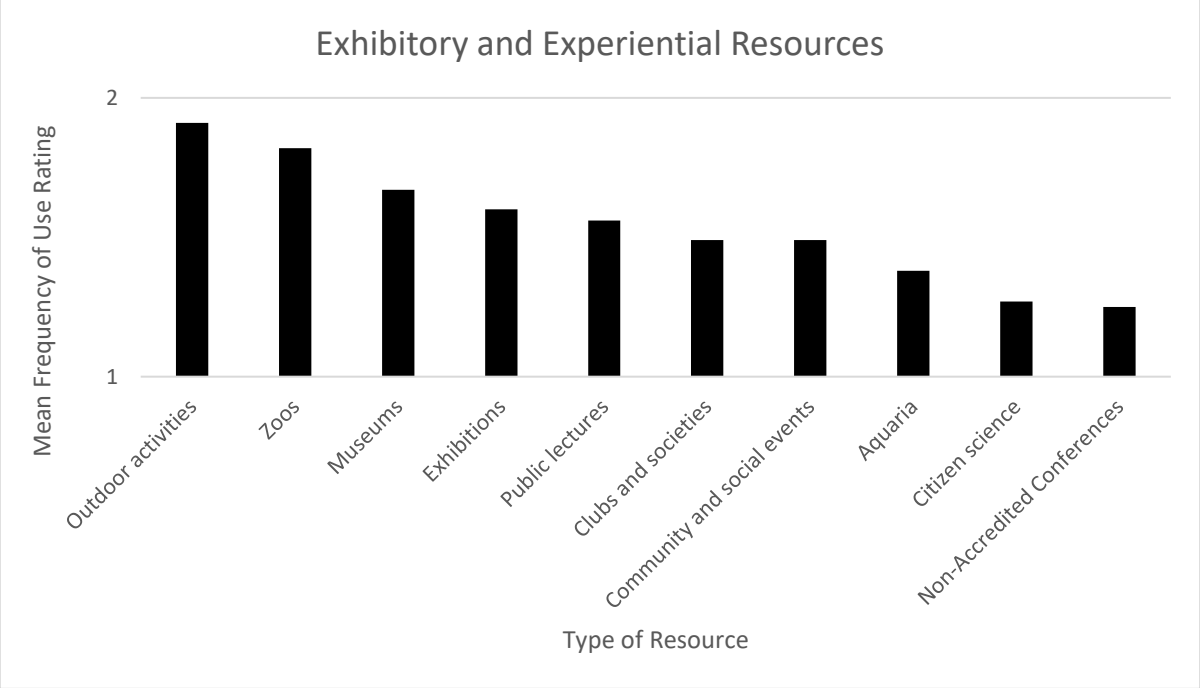
The need for interpersonal sharing of ideas was also evident at the focus group discussions, where participants continued their discussions outside of the meeting room. After the focus groups had ended, the participants proceeded to exchange contact details and website addresses with other members of their group, with the intention of supporting each other in the future.

4.2.4 Exhibitory and Experiential Resources

None of the resources that were categorised as *exhibitory and experiential learning resources* in the questionnaire yielded a mean frequency of use rating above 2. On the Likert scale 2 corresponds to *rarely used* (i.e. 1-10 times in a typical month). Outdoor activities (M = 1.91, SD = 0.87) was the most frequently accessed *exhibitory and experiential learning* resource. Figure 4.4 presents the mean frequency of use ratings of *exhibitory and experiential learning resources* by resource types.

Figure 4.4

The mean frequency of use ratings for exhibitory and experiential sources, by resource type



The results in Figure 4.4 indicate that the participants access *exhibitory and experiential learning resources* with a low frequency. Table 4.3 presents *exhibitory and experiential learning resources* by type and the percentage of the participants who use these. Whence, the percentages in Table 4.3 refer to the number of participants who indicated that they access *exhibitory and experiential learning resources*. This excludes those who selected 1 on the Likert scale, corresponding to *never* accessing these resources. The table shows that over half of the respondents use outdoor activities, zoos and museums as informal learning resources.

Table 4.3

Exhibitory and Experiential Resources by Type and Percentage of Use

Exhibitory and Experiential Resources	Percentage of Participants (N = 91)
Outdoor Activities	63.7%
Zoos	63.7%
Museums	54.9%
Exhibitions	48.4%

Despite the low mean frequency of use ratings for this category, the results in Table 4.3 indicate that a sizeable percentage of the participants accessed *exhibitory and experiential learning resources*, but just not frequently. The mean frequency of use rating for museums is *M* = 1.67, *SD* = 0.70, and 54.9% of participants indicated that they used museums as an informal learning resource. In comparison, the mean frequency of use rating for Facebook is *M* = 1.65, *SD* = 1.14, but only 30.8% of participants indicated they used Facebook as an informal learning resource.

For those participants from rural areas, opportunities to attend the zoo or museums were limited due to the large distances involved. Participant QP02 wrote that they: 'Live in a rural/remote area so many of these resources, although fantastic are not readily available, more than four hour's drive each way to the city'. One participant wrote positively about using *exhibitory and experiential learning resources* and commented on the frequency with which these were accessed: 'For zoos, museums, aquaria, exhibitions, outdoor activities: Maybe attend once a month to see particular science related things, plan potential trips, collect information sheets and activities. Great for photos to use in lessons' (QP091).

While outdoor activities were the most frequently accessed *exhibitory and experiential learning* resource, few elaborated on the activities in which they were engaged. For those that responded to the questionnaire, their home location and the location of their school had an impact on the opportunity for them to access some of the *exhibitory and experiential learning resources*.

4.2.5 Summary of informal learning resources accessed by teachers

Overall, the results suggest that secondary school science teachers are continually engaged in informal learning as a source of PD and use a rich variety of informal resources to inform their teaching and professionality. They concentrate on resources that will provide them with solutions to their individual questions or needs, rather than resources that offer more general answers or information. The specificity of the content and the timing of accessing content impact how frequently the teachers access the informal learning resources. The two categories that are mostly used are *interpersonal communication* (*M* = 3.24, *SD* = 1.03) and *non-interactive resources* (*M* = 3.04, *SD* = 1.07). The least-used categories are

interactive resources (*M* = 1.41, *SD* = 0.78) and *exhibitory and experiential learning resources* (*M* = 1.54, *SD* = 0.69). Within these categories, the four most frequently used resources are conversations with colleagues (*M* = 4.38, *SD* = 0.85); Google (*M* = 4.23, *SD* = 1.00); YouTube (*M* = 4.11, *SD* = 0.97); and books (*M* = 3.80, *SD* = 1.15).

The results indicate that teachers prefer to speak in person with colleagues and access information online through *non-interactive media*, rather than to use *interactive media* resources. While the participants appreciate and actively engage in collaborative learning with their colleagues, this "community of experts" approach does not readily translate into an online community. This is clear in the difference between the mean rating of *conversations with colleagues* (*M* = 4.38, *SD* = 0.85) when compared with any of the interactive media resources, where none of the resources presented were rated above *M* = 2. Social media platforms such as Twitter and Facebook, in particular, do not appear to satisfy the needs of teachers for interpersonal informal learning.

4.3 The teachers' purposes in accessing informal learning resources

The questionnaire requested the participants to write about their 'purpose of accessing each resource' (see Appendix A). Similarly, participants in the focus groups were requested to discuss their 'uses and purpose of accessing informal resources' (see Appendix B, Table 1). The combined data were read multiple times. The various responses were allocated into categories. When a single response fell into more than one category, the categories were modified. This process continued over several iterations until exclusive categories were formed, in which each response could only fit into one category. The categories of purposes that emerged are: (i) *self-teaching content*, (ii) *expanding existing knowledge*, (iii) *meeting the curriculum*, (iv) *networking and belonging to a community*, and (v) *adapting to new technologies*. These categories are discussed in what follows.

4.3.1 Self-teaching content

Some secondary school science teachers are teaching outside their major scientific field of study and some schools have teachers who teach science without

a background in science. This reality was mentioned by a participant in the biology focus group. ‘So this year all our Science teachers are actually teaching science. Last year I was teaching Humanities and English and there was non-science trained people teaching science’ (BG3D). For these groups of teachers, informal PD is used as a means for learning new content. A questionnaire participant stated that they engage in conversations with colleagues for help with content outside of their subject specialisation, ‘non-specialists teaching, i.e. physics/biology’ (QP091). A biology focus group participant stated that, ‘Because you don’t know the topics. I learn the background myself and then I can teach it’ (BG1A). A participant in the chemistry focus group described how they made use of YouTube to further their own understanding of topics with which they had difficulty, ‘I am a visual learner, I understand from videos and not just from chunks of data, so if I don’t understand a concept I go to YouTube.’ (CG2A). When providing their reason for using YouTube questionnaire participants wrote, ‘Improving understanding of new content’ (QP61), and ‘To help understand a topic’ (QP84).

Participants in the biology focus group had a conversation about the need to learn background knowledge before they could teach the subject. Participant BG1C stated that ‘you know, if you studied stem cells you would not have studied marine biology. It is hard to be an expert in everything. It’s specialised.’ The informal learning purpose of *self-teaching* presented itself in close proximity to the purpose of *expanding existing knowledge*. While the two may seem similar, *expanding existing knowledge* constitutes a different type of purpose, as discussed in the following section.

4.3.2 Expanding existing knowledge

Some participants indicated that they needed to expand their existing knowledge to stay up-to-date with new discoveries in science. During the biology focus group discussion, the participants had an animated conversation about the need for teachers to be aware of recent scientific developments. The following excerpts demonstrate this purpose.

> BG1C: ‘I did that at university…in terms of having to learn things like gene technology, and all that stuff, that wasn’t even being, that was cutting edge stuff back then. Back when I was

> in uni, they were still administering bovine insulin. You look at gene technology and the production of insulin and I had to read up.'
>
> BG1A: 'Yeah that's what I've learned, just having to get my own knowledge up.'

While these quotations seem closely related to those in the previous section on self-teaching content, they differ in that the participants already had knowledge of the field of study and viewed their learning as raising their existing knowledge rather than learning new content. The comments made in the focus groups reflect the teachers' motivation to expand their knowledge as a result of personal interest in a topic or skill rather than learning content as a necessity to teach their classes.

None of the participants described situations where formal PD prepared them to stay current with subject content knowledge. Participants spoke warmly and enthusiastically about recent scientific discoveries and enjoyed sharing their knowledge of these discoveries with their colleagues.

4.3.3 Meeting the curriculum

The secondary school science teachers were mindful that they need to adequately address the curriculum. Covering the curriculum was mentioned in both of the focus groups and the questionnaire written responses.

Some excerpts represent this purpose as follows: Participant QP003 wrote that they accessed the online curriculum when they wanted to 'check to see if covering all topics correctly'; participant QP065 wanted to 'crosscheck curriculum against Victoria curriculum/VCE study designs'; and participant QP019 wrote that their purpose for seeking expert advice was to clarify 'new curriculum issues'.

There was a perception among the focus group participants that there exists a degree of vagueness in the VCAA study designs (VCAA, 2018), which compromises teachers' confidence in their capacity to cover the curriculum. This was discussed in the biology teachers' focus group and articulated by participant BG1C, as follows:

> I might be giving my age here, but I started teaching back in the 80s and education was so much different then, because you had a curriculum branch and they would give you printed materials rather than a set of dot points as they do in the VCAA study design. It was actually heavenly; you knew what you were up against. But that's all gone

These results suggest that the secondary school science teachers do not expect that formal PD opportunities alone, or the formally provided curricula, will be adequate for them to teach the curriculum to the level and quality that is expected.

The participants appeared to feel it was not always clear to teachers what was required of them. This motivated them to seek reassurance by accessing online resource banks such as GTAC. The teachers indicated that they compared the resources on GTAC to the resources that the teachers were producing themselves. They also used these resource banks to find resources that they might then use in class.

School-assessed coursework (SAC) is a requirement for all VCE Units 3 and 4 students in Victoria, with the individual pieces of assessment provided internally by the classroom teacher (VCAA, 2018). Producing the necessary resources to be able to cover this area of the curriculum was a motivating factor for the teachers' engagement with some of the informal learning resources. Focus group discussions regularly returned to producing SAC materials. For example, in reference to the Biology Teachers Network (BTN), BG2A noted 'there is a bunch of SACs that get put up there' (BG2A); in reference to GTAC, it was noted 'it is a science centre, they make SACs and stuff, particularly for schools that can't make their own' (BG3C).

A participant stated that Facebook's attraction was mostly in regard to serendipitous, incidental learning that users experienced, which they could later use in lessons to help them to meet the curriculum. For example:

> I did find an article from Facebook that was really useful for Unit 2 about stem cell technology for curing a particular form a cancer. Really good to use as a Springboard to open up other stuff around cancer as well as the stem cell stuff. Which was just bizarre, it just popped up in my Facebook feed and I was that's bizarre, that's just the article I'm looking for my class to read (BG3D)

Teachers' efforts to meet the curriculum also encouraged them to collaborate in networks, as discussed in what follows.

4.3.4 Networking and belonging to a community

The results suggest that the teachers value opportunities to collaborate and network with their peers, as indicated by the high mean frequency of use rating recorded for *conversations with colleagues* in Section 4.2 of this study. The teachers seek collaborations in diverse ways, including joining existing formal teaching communities and networks or starting their own informal communities. Through their responses, the participants indicated some reasons for seeking these collaborations which included wanting to belong to a wider science teaching community and wanting to reduce their workload through information and resource sharing. Formal teaching communities in Victoria include: Science Teachers Association of Victoria (STAV, 2020), Chemistry Education Association, (CEA, 2021), Biology Teachers Network (BTN, 2016) and Vicphysics Teachers' Network (Vicphysics, 2020). Participant BG2A found the 'Biology Teachers Network really, really good'.

Some of the focus group participants stated that they used informal teaching communities and networks. Participant BG3D had 'a couple of teaching groups on Facebook'. Participant CG2B described an informal teaching community 'with teachers outside of the city. We created a Google Drive, and everybody puts things in.' A participant in the chemistry focus group spoke about a community of secondary school educators that had collaborated to share resources, but they also mentioned how the sense of support felt by the members of this community was as important as the resources being shared.

> The list is growing, it is on our system, looking to grow to 30-40. It's just beginning this year, we are starting to put up specialised areas, and the good thing is that it's quite encouraging and builds morale, and young teachers, we can support them, before they give up (smiles) (CG2B)

This statement suggests that many secondary school science teachers, especially newly qualified teachers, may feel a sense of isolation and welcome the opportunity to feel part of a professional community. A participant in the biology focus group spoke of the value in being a part of a specific online teaching community:

> I'm doing the graduate certificate in STEM education and so within that we have a discussion forum on Facebook, which is fantastic, people share resources, what we are doing, and so it's really specific to teaching that particular way (BG3D)

There was also evidence, however, that participants may find difficulties operating an informal network. For example, Twitter was mentioned as a collaborative space but with mixed results:

> I have used Twitter. I used it for a while. It was useful for a bit but became less useful over time… so using it to interact with other educators. And then grew up a professional network and sharing resources and sharing ideas. But the tone of the conversations changed over time, became more negative. Very cyclical (BG2C)

The mixed responses to collaboration on Twitter are consistent with the low frequency of use rating reported in the analysis of Question 1 of this study.

The participants showed enthusiasm for communicating with those engaged in research or potentially being a contributor to research through citizen science projects or as a research assistant. This was stated by participant QP017, in reference to engaging in citizen science, who wrote they participate 'once a year e.g. Aussie backyard bird count'.

Overall, the secondary school science teachers appear to seek opportunities to collaborate where possible, whether through conversations with colleagues, attending teaching conferences and/or setting up informal networks.

4.3.5 Adapting to new technologies

New technological developments require the teachers to be flexible in adopting frequent changes in ICT. The participants mentioned some frustration at the demands of keeping abreast of changing technology or new technological systems:

> These new things come in all the time. My problem with the app thing is, there is always a new one, that does the same or similar to what the old one does. And we are not getting our head around how to use that one properly in our classroom before we are being pushed to use another one. Well I'm finding that impossible anyway (BG3A)

A similar view was shared by BG3C who found 'there is not enough said about the rate at which things are changing'.

While many teachers might agree that the advent of communication technologies, and school intranet systems, along with the ubiquitous use of laptops by teachers in class, has made significant improvements to the quality of the teaching they provide, other unexpected impacts have started to emerge. Adopting and learning to use technologies such as school e-mail, and software such as Microsoft Office, appears to have crossed from an informal expectation to a formal job expectation in most schools.

A participant from the chemistry focus group commented: ‘sometimes I think the challenge for us teachers is to learn this technology’ (CG2B). Another participant agreed stating that ‘for us teachers, we have learned at school it was not such a technology savvy [world], when we were growing up, so that as teachers, the access is a bit (pause)…the learning curve is huge for us as well’ (CG2A).

The participants did not discuss how they were adapting to use these new technologies and an assumption may exist that teachers will learn to use these technologies either through trial and error or through conversations with either teaching colleagues, or work colleagues in the ICT department of their schools. This was not stated directly but a participant in the questionnaire wrote that their purpose for engaging in conversations with colleagues was to get ‘help with understanding some equipment/technology or something I don’t know’ (QP006). One of the focus group participants suggested engaging with trainee teachers who might have ideas on using technology effectively:

> I would maybe even check in with what they are doing, because there are things they would tell us to use, and teachers at the school had never heard of, so it can be good to see what the new generation are using, who grew up with that technology that you are not as comfortable with, to see how best to use it. (BG3C)

Participants also acknowledged the role of their students in assisting them. In the biology focus group, teachers spoke of listening to their students’ feedback on new technologies and being willing to adopt those technologies. The following conversation was in reference to using phone applications, commonly abbreviated to *apps*.

> BG3A: ‘Yeah, and they are like Miss, what about this one? And I’m like yeah, that’s awesome. Because I think it is a two-way street. Because it is important to talk to colleagues and other teachers, but it is important to talk to the kids as well.’
>
> BG3D: ‘Definitely, the kids know where it is at.’

One of the few users of WhatsApp described using it for ‘instant communication with parents and students’ (QP077).

These results indicate that teachers feel it is a challenge to adapt to new technologies, yet little direct evidence emerged on how they are adapting to these changes.

4.3.6 Summary of the teachers’ purposes in accessing informal learning resources

The examination of the teachers’ purposes in using informal learning resources to support their PD revealed diverse purposes encompassed within five major categories. From the five categories described above, three categories are directly related to meeting the needs of teaching. These are the categories: *self-teaching content*; *meeting the curriculum*; and *adapting to new technologies*. The two other categories: *networking and belonging to a community*; and *expanding existing knowledge*, seem to meet more holistic needs that extend beyond the classroom teaching. These last two categories relate to aspects that are concerned with development of professional identity and belonging to a community of practice, rather than the delivery of the curriculum in class. Overall, the teachers portray broad purposes in their use of informal science learning resources, where personal needs and professional needs seem to intertwine.

4.4 Relationship between frequency of accessing resources and years of experience in science teaching

The questionnaire data were analysed to determine if there were any statistically significant differences between the mean frequency of use rating for each of the 31 informal learning resources and the participants’ number of years teaching experience. To determine if differences exist, a Welch ANOVA test was conducted (Moder, 2010). To identify between which groups of participants these statistically significant differences occurred, a Games-Howell *post hoc* test was

used (Games & Howell, 1976). In what follows, the results of these tests are presented.

The aim of the Welch ANOVA test is to examine whether the variability of responses between the age groups is significantly greater than the variability of responses within the age groups. The *F*-value signifies the ratio between the two types of variabilities (between and within) (De Winter, 2013). When the ratio is equal to unity, the two types of variabilities are the same. In other words: The age group has no effect on the distribution of the responses (Moder, 2010). The *F*-distribution has two different degrees of freedom: *df1* is derived from the number of groups being compared, using the formula *n*-1, where *n* is the number of groups being compared. In the current study there were three groups, yielding a *df1* value of 2. In this case: early career, mid-career and advanced career. The *df2* is derived from the number of participants in each category (Allwood, 2008). A value of $p < 0.05$ indicates significant difference between the groups. Table 4.5 presents the results of the Welch ANOVA test.

Table 4.5

Results of the Welch ANOVA Test (n = 91)

Resource Type	F[a]	df1	df2	Sig. (P)
Twitter	0.5	2	54.69	0.59
Facebook	0.3	2	58.34	0.71
Skype	2.3	2	40.71	0.12
Online Courses	1.1	2	54.07	0.36
Snapchat[b]	.	.	.	.
WhatsApp	0.7	2	56.37	0.50
Instagram	0.5	2	54.70	0.61
Blogs	0.0	2	55.69	0.98
Discussion Forums	0.0	2	53.61	1.00
Google	1.1	2	54.84	0.36
Television Programs	3.8	2	54.84	0.03*
YouTube	1.1	2	56.07	0.35
Online Resource Banks	0.4	2	54.55	0.68
Online Curriculum	0.1	2	55.28	0.95
Conversations with Colleagues	0.1	2	56.97	0.91
Conversations with Friends and Family	1.3	2	53.96	0.28
Expert Advice	0.0	2	55.81	1.00
Zoos	0.4	2	57.91	0.66
Museums	1.1	2	52.23	0.35
Aquaria	2.7	2	53.95	0.07
Exhibitions	0.0	2	57.96	0.95
Outdoor Activities	0.2	2	53.55	0.85
Community and Social Events	0.3	2	55.49	0.75
Citizen Science	0.1	2	52.87	0.95
Public Lectures	1.1	2	53.33	0.33
Clubs and Societies	0.6	2	54.02	0.53
Non-Accredited Conferences	0.4	2	52.19	0.68
Books	0.6	2	57.95	0.56
Newsletters	8.1	2	49.66	0.00*
Journals	1.1	2	56.51	0.32
Magazines	1.7	2	55.55	0.20

a. Asymptotically F distributed.
b. Robust tests of equality of means cannot be performed for Snapchat because at least one group has 0 variance.

The results indicate that of the 31 informal learning resources only two resources showed statistically significant difference. These resources are *television programs,* $F(2, 54.84) = 3.8$, $p < 0.05$ and *newsletters*, $F(2, 49.66) = 8.1$, $p < 0.01$. The mean frequency of use rating of these resources depends on the years of

teaching experience. To find out in which of the three career stages, early, mid and late career, the mean frequency of use ratings for these two resources differ, a Games-Howell *post hoc* test was conducted (Games & Howell, 1976). A Games-Howell test compares the mean values for two groups to identify if statistically significant difference exists between the means of those two groups. In the current study it compared the mean values for early career teachers with mid-career teachers and compared the mean values for mid-career teachers with advanced career, and finally compared the mean values of early career teachers with advanced career teachers. A Games-Howell test was used in preference to a Tukey *post hoc* test (Shingala & Rajyaguru, 2015). A Games-Howell test can be performed where the variances are unequal and the sample sizes are unequal (Shingala & Rajyaguru, 2015), as is the case in the current study. Table 4.6 presents the results for the Games-Howell test on *television programs* and *newsletters*. A value of $p < 0.05$ indicates a significant difference exists between the groups.

Table 4.6

Results of the Games-Howell Post-Hoc Test (n = 91)

Resource	Career Stage	*N*	Mean	*SD*	Std. Error	Difference Between Means	Sig,
Television Programs	Early Career	35	2.03	0.82	0.14	-0.66	0.02*
	Advanced Career	26	2.69	1.01	0.20		
Newsletters	Early Career	35	1.54	0.61	0.10	0.88	0.00*
	Advanced Career	26	2.42	1.07	0.21		

The Games-Howell test on *television programs* indicates a statistically significant difference between *early career teachers* ($M = 2.03$, $SD = 0.82$) and *advanced career teachers* ($M = 2.69$, $SD = 1.01$) for $p < 0.05$, indicating that *advanced career teachers* have a higher mean frequency of use rating for *television programs* compared to *early career teachers*.

The Games-Howell test on *newsletters* indicates a statistically significant difference between *early career teachers* ($M = 1.54$, $SD = 0.61$) and *advanced career teachers* ($M = 2.42$, $SD = 1.07$) for $p < 0.01$, indicating *that advanced career*

teachers have a higher mean frequency of use rating for *newsletters* compared to *early career teachers*.

Across the three career stages only in two out of the 31 resources, there were statistically significant differences in the use rating across the career path. The results suggest that on the whole (across 29 out of 31 resources), the secondary school science teachers in this study can be considered to form a homogenous group across all years of teaching experience regarding their frequency of accessing informal learning resources. This result aligns well with all other results presented so far, which portray the teachers as using a diverse array of resources for diverse purposes in an active and ongoing manner.

4.5 Summary of the findings

The analysis of the data in this study reveals four significant findings. The first suggests that the teachers prioritise interpersonal communications as a form of informal PD above any other form of interactive communication. Online interactive communications are not a substitute for face-to-face contact. This is clear in the more than two-fold difference, between the mean frequency of use rating for *conversations with colleagues* (M = 4.38, SD = 0.85), as compared with the *interactive media resources*, where none had a mean frequency of use rating above 2 on the Likert scale. The lower mean frequency of use ratings are those associated with social media platforms.

The second finding suggests that the secondary school science teachers prefer *non-interactive resources* which provide tailored information, where they can find an immediate answer to a question. Resources such as YouTube and Google are preferred over non-specific resources such as *newsletters* and *online courses*.

The third finding suggests that there are no major differences in the rate of accessing the various resources by teachers with varying number of years of science teaching experience. This indicates that the secondary school science teachers in this study can be considered to be a homogenous group in regard to informal resources accessing. They share similar informal learning habits regardless of the number of years they have been teaching. It may also reflect the

level of interpersonal communication which occurs in their schools. More generally, it appears that the teachers may share ideas with their colleagues about which informal learning resources are the most useful.

The fourth finding suggests that there are two main purposes for the teachers' informal learning. These are to develop professional identity and to aid their teaching. For developing professional identity, teachers engage in networking in an effort to belong to a wider teaching community. They also seek to expand their existing knowledge through informal learning. To aid their teaching, the teachers self-teach content to help them meet the curriculum. They also need to adapt to constantly changing technologies which are used in their daily work and also aid their teaching.

The next chapter discusses these results and their implications. Questions which emerged as a result of this study are also discussed and suggestions for further research are proposed.

5. DISCUSSION

The Discussion is organized in accordance with the four main findings of this study. First, I discuss teachers' prioritization of face-to-face communication as a form of informal learning. This is followed by examining the meanings and implications of teachers' preference for non-interactive resources over interactive resources. I then discuss the finding suggesting that teachers access informal learning resources in a similar way across their career path. This leads to considering teachers' purposes in accessing informal learning. Finally, I critique the PD accreditation requirements, on the basis of the accumulative evidence obtained in this study. The chapter concludes by considering the implications and limitations of this study.

5.1 Prioritising face-to-face communication as a form of professional development

The most frequently accessed informal learning resource found in this study is the item *conversations with colleagues*. All 91 of the study's participants used conversations with colleagues as a source of informal PD. The results suggest that the secondary school science teachers gain a significant portion of their informal learning experiences from their colleagues and appreciate face-to-face communication. These findings were equally applicable to all the participants, whether they were teachers working at large schools with a large group of science teachers, or teachers working in small schools, with few subject specialists and limited opportunities for conversations with science educationists.

This supports research by Roxå and Mårtensson (2009) on university academics which found that academics relied on conversations with a network of a few significant other colleagues as they constructed, maintained, or changed their understanding of teaching and learning (2009, p. 214). Through the lens of socio-cultural theory, they found that some of these conversations could have an influence on how teachers develop a new understanding of teaching or even significantly alter their conceptions of teaching (Roxå & Mårtensson, 2009).

Several researchers have noted that online sessions did not provide the same potential to build a strong sense of community as compared to face-to-face interactions (Lantz-Andersson et al., 2018; Maher & Prescott, 2017; Mitchell et al., 2010). I suggest that the results of the current study indicate that face-to-face interactions are necessary for the teachers to feel a sense of social presence and this has an impact on informal PD. The science teachers' unequivocal need for face-to-face conversations may be explained by previous studies which indicate that learning is enhanced when learners feel emotionally and personally connected (Dixson, 2015; Garrison & Arbaugh, 2007; Kehrwald, 2008). Learners also need to feel a sense of social connectedness to a group (Garrison et al., 1999; Holmes et al., 2010; McConnell et al., 2013; Shea et al., 2006).

Opportunities for developing online PD activities are sometimes presented as an alternative to, or improvement on, face-to-face interactions (Dede et al., 2009; Russell et al., 2009). The present study's findings do not support these claims, but rather confirm previous findings by Powell and Bodur (2019) who found that participants perceived the lack of social interaction and collaboration in online PD as a weakness. Other research into online learning environments, such as Massive Open Online Courses (MOOCs), indicates dropout rates of up to 90% (Hew & Cheung, 2014). This high attrition rate may be due to the inability of MOOCs to provide the kind of social environment that is conducive to sustained engagement and learning (Bradshaw et al., 2017; Yang et al., 2013). It has also been suggested that the highly time-flexible nature of these courses, the low degree of pressure and low stakes on the part of the learners to participate, also contributes to low levels of teacher engagement in online PD activities (Fiel et al., 2018). Online teacher communities on platforms such as Twitter have also been found to suffer from high attrition rates (Xing & Gao, 2018), again suggesting that the lack of face-to-face interaction may be detrimental to sustaining such communities.

The finding, regarding the contribution of informal discussions to enhancing professionality, may have implications in the field of measuring PD outcomes. The literature presents extensive debate related to the measurement of learning outcomes in PD (Desimone, 2009; Guskey, 2002; Kennedy, 2005; King, 2014).

Most of the studies focus on measuring acquisition of pedagogical skills, conceptual development and knowledge (Flores, 2005; Garet et al., 2001; Kennedy, 2016; McNeill & Knight, 2013). However, the present study sheds light on another type of outcome, which is tacit and inferential in nature. This refers to the enhanced professionality gained through informal conversations. This learning outcome is unlikely to be measurable. Yet at the same time, it was ranked by teachers as the most frequently used informal learning resource. It is important to note that formal PD activities also suffer from their inability to measure outcomes for both teachers who participate as well as their students (Osman & Warner, 2020; Van Driel et al., 2012). The importance of *conversations with colleagues*, further highlights the challenge of making invisible learning outcomes visible (Byrne et al., 2010; De Laat, 2012); and the decades old debate regarding what constitutes a learning outcome and how to describe it (Butler, 1978; Chalmers & Gardiner, 2015; Choi & Jacobs, 2011). Thus far this aspect was not included in the PD outcomes measurement debate (Avalos, 2011; Martin & Scantlebury, 2009). However, the importance of this aspect highlights the need for further research related to the role of *conversations with colleagues*, in science education informal PD (Jones & Dexter, 2014).

The finding that teachers extensively use face-to-face conversations with their colleagues as a form of PD has broad implications for both informal and formal PD. Significant conversations with colleagues are characterized by mutual respect, reciprocity, and the sharing of values and practices. These also include some degree of risk and vulnerability as conversation partners wrestle with the uncertainty, complexity, and even failure all of which are inherent in teaching. These conditions might be created intentionally by teachers and academic developers, or they might emerge less deliberately (Huang & Wang, 2021; Thomson & Barrie, 2021). Regarding informal PD, educational policy makers, school principals and educationists, should aim to create spaces that allow for such unstructured and unplanned conversations to take place. Such spaces may be physical spaces, at schools, such as staff working spaces designated specifically for science teachers or temporal spaces, such as providing time slots, in which all science teachers at a school are free from teaching and are actively encouraged to meet for informal conversations (Benbow & Lee, 2019; Thomson et al., 2020). In a

study by Jones and Dexter (2014) teachers agreed that by aligning planning periods within content areas, informal interactions between teachers of the same content area were facilitated which, in turn, promoted informal collaborations (p. 377). The participants in the current study noted that opportunities for informal conversations and collaboration at their schools were often too limited.

In regard to formal PD, the findings of the present study suggest that formally organised PD activities should provide within the planning of the PD activities, opportunities for non-structured exchanges between teachers. Other opportunities include forming *special interest groups*, where science teacher conference delegates can elect to join with other participants in workshops or in discussion groups on topics which they feel would be of most value or interest to them, rather than lecture-style delivery of content. This may increase teachers' engagement and satisfaction with the PD activity. Professional networks such as the Biology Teachers Network (BTN), Chemistry Education Association (CEA) and the Vicphysics Teacher'' Network could provide more positive outcomes for their members by introducing increased opportunities for teachers to meet face-to-face for unstructured conversations. These formal networks could also be used to foster informal communities among teachers in schools that are in close proximity to each other and those who are teaching subjects in the same discipline. This could be achieved by providing information such as school e-mail addresses and subject specialisms of science teachers who are interested in participating.

The results of this study also confirm that facilitating opportunities for face-to-face, peer conversations among teachers constitutes a necessity rather than a luxury in the context of teacher PD. While the outcomes and effectiveness of these conversations may not be measurable, they clearly occupy a central role in secondary school science teachers' informal PD.

5.2 Non-interactive resources provide on-time tailored information

The second finding of this study highlights teachers' need for tailored on-time information. Teachers, as professionals, are often time poor and some participants stressed that they did not have enough time to look at all of the

resources that are available to them. What appears to matter most is that a resource can answer the teacher's immediate, specific questions. These findings are reaffirmed by previous findings by Kostoulas et al. (2019) who examined the ways in which teachers prefer to stay informed about research. They found that 67.6% of participants searched internet-based sources, whereas only 36.7% of the participants accessed information through newsletters. A similar difference was found in this study. Differences were also found when comparing *non-interactive resources* such as Google, YouTube and books to *interactive resources* such as Facebook and Twitter. Together the findings support my contention that the preference for Google, YouTube and books could be because unlike all the other examined resources, they provide tailored information, on time. This supports the results of a study by Hogan et al., (2018) which found that many formal PD programs in Australia are viewed by teachers as being over-priced, and often regarded as just an opportunity for education service providers to advertise their products. Participants in the study by Hogan et al. (2018) found that for many teachers commercially available formal PD resources has little relevance and does not address their learning needs.

Searching for specific information in a short space of time has been described in the literature as 'just-in-time PD' (Greenhalgh & Koehler, 2017; Hamel et al., 2012; Jackson, 1999; Jones & Dexter, 2014). Just-in-time PD appears to be crucial to meeting teachers' learning needs. Reading (2017) suggests the reason that many PD activities fail in their objectives is that they provide 'just-in-case' training instead of 'just-in-time' training (p. 50). An example of the difference between these two types of PD can be seen in the use of Google (M = 4.23, SD = 1.00) when compared to *newsletters* (M = 1.95, SD = 0.94). The information in a newsletter may never be of use or benefit to the receiver. The information is provided, 'just-in-case' it is useful. In searching Google for information, teachers can obtain answers 'just-in-time'.

The high mean frequency of use rating in this study for resources such as Google, YouTube and *books* highlights the importance of autonomy and agency in informal PD, where teachers direct their own learning in meeting their individual work needs. This relates to what Molla and Nolan (2020) describe as *inquisitive*

agency, when teachers actively seek learning opportunities. The importance of free-choice in regard to PD activities was noted by Masuda et al. (2013) who found that advanced career teachers would rather attend voluntary PD sessions, that they felt were worthwhile, than mandatory sessions, which they found to be less useful (Masuda et al., 2013, p. 10).

The theory of self-determination provides a useful context for explaining the need for autonomy and agency in teachers' informal PD (Deci & Ryan, 2004). The theory proposes that adults tend to direct themselves to learning something new if they have an expectation that the object of learning will be valuable to them in their work situation (Louws, Meirink, et al., 2017, p. 172). The present study adds more specificity to the theory's claim, by clearly identifying that the resources that address these needs are non-interactive media resources, rather than any general PD. Modern technology seems to provide teachers with more freedom and agency in seeking information than ever before. I would suggest that further research should focus on exploring which internet platforms are most suitable for addressing teachers' needs, and the type of support that teachers require in order to make best use of *non-interactive online resources*.

In recent years, YouTube content has evolved from user-generated content (UGC) to professionally generated content (PGC) leading to what some authors refer to as the *institutionalisation* of YouTube (Kim, 2012). This may have increased YouTube's credibility as a source of information for science teachers, with reputable broadcasters such as National Geographic producing high-quality resources on this platform. Through YouTube, a user can also access a number of science-specific channels producing videos on a wide range of topics. These include channels on the physical and natural sciences such as Minute Physics (2020), mathematical sciences such as Numberphile (2020), and biological sciences such as CrashCourse (2020). Some YouTube channels are tailored to secondary school science curricula. Bozeman (2020) is a YouTube channel which presents videos that are tailored to the learning needs of students studying the Advanced Placement (AP) curriculum in the USA. The AP curriculum offers college-level curricula and examinations to high school students. Another channel, Bitesize (2021), presents videos that are tailored to the UK curriculum. Channels

such as these offer teachers an opportunity to quickly find resources that will provide them with relevant information on specific topics when they need it. The large number of videos being produced by the various YouTube channels increases the probability of finding highly specific, useful information.

5.3 The relationship between accessing resources and stages of the career

In regard to accessing resources the results suggest that the secondary school science teachers' preferences, overall form a homogenous group across the years of teaching experience. This finding confirms the results of other studies which found that demographic variables such as gender, educational qualification, age, and full-time or part-time status are unrelated to teacher PD outcomes (Evers et al., 2016; Hildebrandt & Eom, 2011).

When considering informal PD, most of the resources are accessed through ICT. Guo et al., (2008) investigated the ICT competence among preservice teachers, in relation to their age groups. Their findings, which suggest there are no age differences, may provide the underlying explanation for the present study's results. Since ICT competence does not seem to pose an age-related barrier, the participants of this study accessed similar resources regardless of their career stage.

The finding of the current study that the science teachers overall form a homogenous group across the years of teaching experience provides evidence against research claims suggesting different learning habits between *digital natives* and *digital immigrants* (Prensky, 2001). While today's learners can differ in their access to technology, ICT skill, use and comfort (Bullen & Morgan, 2016, p. 66), I suggest that any limitations in teachers' ICT capabilities may be issues that transcend age categories and years of teaching experience (He & Li, 2019). Such issues need to be addressed as such, rather than assuming that more recent generations of qualified teachers will come preprogramed with a complete range of ICT skills and require no further training, support or PD on ICT use.

5.4 Informal learning for developing professional identity and aiding teaching

The findings reveal that the teachers' purposes in accessing informal learning resources, may be grouped into two main categories: (i) developing professional identity and, (ii) aiding teaching. This finding supports the results of other studies that found there are three main learning outcomes that can be observed in teachers' informal learning. These are: (i) development of professional attitudes and identity, (ii) increased pedagogical knowledge and skills, and (iii) increased subject knowledge (Kwakman, 2003; Kyndt et al., 2016; Lohman, 2006; Mushayikwa & Lubben, 2009). In the sections that follow, these learning purposes of *developing professional identity* and *aiding teaching*, are discussed sequentially.

Science teacher *professional identity* affects how teachers view themselves as professionals in their work (Canrinus et al., 2011; Coldron & Smith, 1999). *Professional identity* is socially constructed and constituted and is not something that teachers have but something that emerges through teaching and learning practices in order to make sense of themselves as teachers (Beijaard et al., 2004; Coldron & Smith, 1999). The participants of the current study developed their professional identity in the following ways: (i) networking and belonging to a community; and (ii) expanding their existing science content knowledge.

In regard to networking and belonging to a community, some of the participants stated that they collaborated with their peers through online communities and conversations with colleagues. These participants accessed informal learning resources such as online forums, Google Docs and *interactive media* such as Facebook and Twitter, to network and belong to a community, rather than to seek answers to specific questions or to explicitly learn something new. This result provides evidence that some teachers engage in informal interactions with their peers to help them in defining their science *teacher identity.* Belonging to a professional community allows science teachers to be, and to be recognised as, a particular type of person (Coldron & Smith, 1999; Varelas, 2012). This also relates to the concept of *recognitive agency* (Molla & Nolan, 2020) where teachers demand to be valued and respected for their professional work. Networks and communities also provide teachers with a supportive community of practice in which to develop their use of subject and educational language (Woolhouse &

Cochrane, 2015); and to share their knowledge and connect with other like-minded colleagues (Prestridge, 2017; Tour, 2017; Visser et al., 2014). Teachers create and recreate their image of themselves as members of a professional community (Sutherland et al., 2010). Such interactions have been linked to positive identity characteristics including raised confidence and a sense of collegiality (Kelly & Antonio, 2016; Pedretti et al., 2008). Developing networks and communities outside of teaching such as collaborating with scientists in industry and universities has also been shown to help in developing science teachers' identity (Caton et al., 2000; Drayton & Falk, 2006; Tanner, 2000).

The current study found that some science teachers access informal learning resources to expand their existing knowledge of science content which, in turn, develops their *professional identity*. This supports the results of a study by Sheffield et al. (2016) whose *Reflective Identity Formation Model* found that teachers reflect on their learning, and that they consider how their skills impact upon their professional identity through increased competency. Irving-Bell (2018) found that subject knowledge is a core part of establishing positive professional identities. Science teachers' *professional identity* is rooted in their perception of the world through a scientific lens, and value systems (Beijaard et al., 2004; Desimone & Stuckey, 2014; Helms, 1998; Little, 1993). While expanding existing knowledge may appear to be similar to the purpose of aiding teaching, there is an important distinction. Expanding existing knowledge is motivated by the science teacher's interest in science for personal satisfaction and enrichment. This aligns with *self-concordant* work motivation which refers to an experience of personal choice rather than external pressure (Roth et al., 2007). This reflects engagement in informal learning out of curiosity and interest, derived from their sense of identity (Ryan & Deci, 2000; Tadić et al., 2013; Vansteenkiste et al., 2009). Science teacher *professional identity* is dynamic and continues to change and evolve throughout a teacher's career (Avraamidou, 2014; Day et al., 2005; Prytula & Weiman, 2012). In this regard teacher *professional identity* development is also directly linked to lifelong learning (Beijaard et al., 2004; Day, 2002). It also relates to Clarke and Hollingsworth's (2002) *Interconnected Model of Teacher Professional Growth* which connects the personal domain of knowledge, beliefs, and attitudes to enactment, to the domain of practice which allows for professional experimentation.

The second purpose for which the participants in this study access informal learning as a source of PD is to aid their teaching. Teachers may be prompted to engage in informal learning due to an immediate work need, such as preparing a lesson or completing an administrative task. Teachers need to have confidence in their content knowledge to motivate and sustain science learning in students (Adams & Gupta, 2017). This stimulus to learn, is related to the social psychological model of *work stress*. The model proposes that workers learn new things in order to meet the demands of their job (Kwakman, 2003). This includes: (i) teaching themselves science content; (ii) meeting the curriculum; and (iii) adapting to new technologies. In an Australian context, these purposes relate to the Australian Professional Standards for Teachers (APST) which requires that teachers have professional knowledge, whereby they know the content and how to teach it (AITSL, 2017). To do this, 'teachers should know and understand the concepts, substance and structure of the content, and have teaching strategies for the teaching area which they teach' (Standard 2.1). Teachers are also expected 'to use the curriculum to design learning sequences and lesson plans' (Standard 2.3); and, 'implement teaching strategies for using ICT to expand curriculum learning opportunities for students' (Standard 2.6).

Participants in the current study confirmed the findings of Weldon (2016) who established that there is a significant number of teachers who are teaching out-of-field. In particular, Weldon found that the percentages of secondary school science teachers teaching out-of-field in 2013 were: 14% (biology), 18% (chemistry), 23% (physics) and 10% (general science), with the majority being teachers with less than 5 years' teaching experience. Australia has one of the highest rates of out-of-field teaching internationally (Hobbs & Törner, 2019; Kenny et al., 2019; Marginson et al., 2013) with Australian students being more likely than any other OECD country to be enrolled in schools without specialist mathematics or science teachers (Marginson et al., 2013; Productivity Commission, 2012). Developing the necessary CK and PCK requires ongoing learning, as teachers prepare for individual lessons; the results of the current study appear to suggest that many teachers are turning to informal PD to meet this ongoing work demand through teaching themselves the necessary CK.

The current study found that the participants also access informal learning to verify that they are adequately meeting the curriculum requirements. The participants expressed frustration in relation to the lack of clarity in the Victorian science curriculum documents. This finding suggests that teachers spend more time than they would like on interpreting the curriculum requirements. To address this need, the participants described accessing informal learning resources such as the online curriculum and discussion forums as well as conducting *conversations with colleagues*. The participants also complained about the amount of time they felt was wasted in efforts to find classroom-ready resources that are compatible with the curriculum. Participants in this study also complained of the abundance of commercially available resources available which means they could spend hours looking over resources to find one that was appropriate to their needs. This is in-line with the findings of Burch (2009) and Hogan et al. (2018) who found that the creation of standardised national school systems increases opportunities for private providers to become major suppliers to schools across local education markets. Participants in the current study found that they were constantly reviewing materials from education providers. Again, this appears to confirm the findings of Hogan et al. (2018) whose participants described endless emails from education service providers with requests for meetings to showcase new products (p.154). I suggest that the significant amounts of time teachers spend looking through these resources and deciding which resources are useful requires teachers to reflect on what constitutes a good or bad teaching resource.

To meet the VCE curriculum requirement for SAC, individual pieces of assessment are provided for students in each school by the subject teachers (VCAA, 2018). Schools may be audited by the VCAA to ensure that these SAC tasks align with the requirements of the accredited VCE Study Design and the VCE assessment principles (VCAA, 2018). Producing the necessary resources to be able to cover this area of the curriculum was a motivating factor for a number of participants to access informal learning resources. In some cases, the teachers described seeking reassurance, to verify that what they were using for these school-based assessments was adequate.

There appears to be a gap between the curriculum's intention and teachers' perceptions. While the curriculum is framed to provide teachers with more autonomy, the participants suggested that this actually makes it harder for teachers, rather than easier, because they were less sure as to how to achieve the set outcomes of the study design. While there is an international curricular trend to become less prescriptive, more capability-focused, and less disciplinary focused (Ross, 2000), this may form some discrepancy. On one hand the curriculum is open for interpretations, but on the other hand the assessments are closed. This leaves teachers having to navigate on their own as to how to meet the assessment requirements. This may be an explanation for their lack of comfort in this regard. Additionally, the gap between the non-prescriptive curriculum and the closed assessments may provide further grounding for the important role of informal PD in supporting the work of science teachers. I suggest that this issue requires further unpacking and discussions to occur within the field of Curriculum Theory, as well as among science teachers and curriculum developers.

Some of the participants stated that they accessed informal learning to keep pace with technological changes in schools. This includes the challenge of trying to use interactive technologies as part of their classroom teaching and keeping up-to-date with changing technologies both for teaching and for performing administrative tasks. Using ICT for teaching adds a further dimension to PCK, where teachers need to have adequate ICT knowledge in order to integrate technology into their lessons (Jääskelä et al., 2017; Zheng et al., 2019). This ICT knowledge has been included in the term *technological pedagogical content knowledge* (TPACK) (Lin et al., 2013; Mishra & Koehler, 2006; Schmidt et al., 2009; Sheffield et al., 2018). Participants in the current study complained of the difficulty of keeping up with constantly changing technologies in schools and the need to solicit help from both colleagues and their students.

Despite high levels of participation in formal PD activities to raise teachers' ICT capabilities to aid their teaching, only 39.3% of Australian teachers reported feeling prepared for the use of ICT for teaching (OECD, 2019). The finding that secondary school science teachers access informal ICT learning supports the work of Duncan-Howell (2010) who found that a number of teachers gained their ICT

skills either through trial and error, work-based learning, mentoring or from their students rather than through formal PD activities.

While there has been some research into the use of ICT by teachers as pedagogical tools (Drent & Meelissen, 2008; Jung, 2005), little research exists on how teachers are learning to use these tools for other work-related tasks (Reynolds et al., 2003; Steketee, 2005). Adopting and learning to use technologies such as school e-mail and software tools such as Microsoft Office are now an expectation in many schools. Teachers often need time to develop their competences when using new technologies (Bauer & Kenton, 2005; Ensminger, 2016; Liao et al., 2017). This includes time to explore and experiment with the technology.

5.5 Professional development and teacher accreditation

The findings of this research call for re-examination of accrediting bodies' requirements for annual PD. Teachers in Victoria are required to renew their registration annually through the VIT. The VIT requires that teachers complete a minimum of 20 hours of PD each year to renew their registration (VIT, 2019). Many other countries and jurisdictions have similar requirements for teachers (Scheerens, 2010). The findings of the current study suggest that the science teachers substantially exceed this requirement, thus putting this requirement in question. There is also a debate over whether there is convincing evidence of a direct link between the imposition of PD requirements for annual accreditation and improved student learning outcomes (Adoniou & Gallagher, 2017). Given this lack of evidence for imposing annual requirement as a causal factor for improving student outcomes, it has been suggested that the motivation for such accountability is more about politics than education (Adoniou & Gallagher, 2017).

This study did not collect data counting the absolute number of hours which the teachers devote to their informal PD. Instead, the frequency of accessing informal resources was used as a proxy to measure the amount of time the participants engaged in informal PD. The mean frequency of use rating for *conversations with colleagues* (M = 4.38, SD = 0.85), Google (M = 4.23, SD = 1.00) and YouTube (M = 4.11, SD = 0.97) show that the participants are accessing these

resources between 20 and 30 times in a typical month. All 91 participants access at least one of the informal learning resources as a source of PD more than 10 times in a typical month. Eighty-six of the 91 participants access four or more informal learning resources at least 10 times a month. This is more than 40 uses of informal learning resources per month, suggesting that the number of hours the teachers spend annually on informal PD may be significantly higher than is currently being recorded by teachers on the *MyPD* function of the VIT website. A study by Duncan-Howell (2010) found that teachers who are members of online communities spend between 1-3 hours per week participating in online communities, representing an additional 60-80 hours per year of professional learning. Such a result would appear to support the claim that teachers are engaged in significantly more than 20 hours of PD annually.

The large number of hours which the teachers invest in their PD is in contrasting difference to the VIT requirement, which expects a meager 20 hours PD per year, inclusive of informal learning. The discrepancy between the VIT requirement and the actual time spent on PD begs the questions: What is the purpose of the VIT requirement, and does it add value to teaching? I suggest that in the current technological era, this re-accreditation requirement has become redundant. While teachers' way of cultivating their professionality has drastically changed, this is not reflected in the re-accreditation requirements. When it comes to PD, the VIT re-accreditation system seems out of pace with these fundamental changes that have been occurring in the science teaching profession and, in fact, may be a hindrance to teachers in performing their duties, given that some teachers are audited each year and need to provide evidence of participating in PD.

5.6 Study Implications

This study highlights the important role of informal learning in the daily life of science teachers in Victoria. It is evident that informal learning contributes not only to enhancing the teachers' technological pedagogical content knowledge, but also to the lifelong development of their *professional identity*. There are theoretical and practical implications of the findings. From a theoretical perspective, I suggest that this study changes our understanding regarding the role and value of informal

learning across the careers of science teachers. The study also assists in broadening the conceptualisation of informal PD. It clearly identifies the types of informal learning resources, the need which they serve and the purposes. Further research is required in developing appropriate evaluation methods of informal PD and various means by which to facilitate this ongoing and unaccounted for PD which is so prominent in the lives of science teachers.

From a practical perspective, the findings clearly highlight the misalignment between PD accreditation requirements and teachers' daily unaccounted participation in informal PD. As the study shows, teachers voluntarily participate in PD, more hours than formally required. This clearly suggests that the requirement is not keeping up with technological changes and it appears to be outdated. It is suggested that accreditation bodies take note of this research outcome and consider adopting accordingly.

Similarly, principals, and organisers of PD need to develop more awareness regarding the informal PD needs of science teachers and to facilitate these accordingly. Educational software developers may further assist by developing platforms tailored for the on-time learning needs of teachers.

The data analysed in the current study were collected in 2017, but this thesis was submitted in 2021. In March 2020 the COVID-19 pandemic closed schools across the state of Victoria in Australia, along with many schools in other states and countries. During this closure some secondary school teachers delivered lessons to students through online platforms such as Zoom, Microsoft Teams and Google Hangouts. In addition to severe disruptions to teachers and students alike, COVID-19 presented unexpected contingencies to the education system as a whole. In particular, the notion of *aiding teaching* might have changed significantly due to the need to develop new ways of teaching synchronously and asynchronously. Further research is required for developing understanding as to how teachers use informal learning to aid their teaching during abnormal circumstances such as those imposed by the pandemic.

5.7 Study Limitations

Although the study was confined to Victoria, the analysis and discussion have been constructed with reference to the international literature. There is a need for further research in Australia and internationally in order to identify the extent to which the findings may be generalised.

For the questionnaire, a convenience sampling technique was used. The results of the study may therefore be biased towards the population of secondary school science teachers who attended the conferences where the data were collected and who were also willing to participate in the study.

A further limitation lies in regard to the number of secondary school science teachers who are teaching in Victoria, and the corresponding tertiary qualifications of these teachers. Surprisingly, this important information has so far not been collected by any of the relevant bodies. With the lack of official data, a calculation was performed to estimate the number of secondary school science teachers in Victoria in the various discipline areas. These estimates are likely to be slightly inflated due to possible multiple counting of teachers who teach more than one science subject.

6. CONCLUSION

While conducting this research on science teachers' informal learning, I was continuously confronted by the striking gap between the extensive and fundamental role of informal learning in the professional life of science teachers, and the scarcity of theory and literature, underpinning this field of research. The findings of this study draw attention to this under-researched field. These highlight the need to develop a theoretical framework for deepening our understanding as to what it means to be a science teaching professional in the 21st century.

Appendix A. Written Questionnaire

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Sources of information that science teachers use to inform their teaching and professionality

Thank you for your participation in this research project

In this study we would like to learn about the sources of science information that you use for preparing your classes and developing your science teaching practices.

A. Sources of science information.

Below are five tables presenting five types of resources that can be used for obtaining science information. The types of resources are:

- Interactive media (Table 1);
- Non-interactive media (Table 2);
- Interpersonal communications (Table 3);
- Exhibitory information and experiential learning (Table 4); and,
- Printed materials (Table 5).

We are interested in learning about your use of these resources in a typical month when you are teaching. We are interested in learning about how you use these resources for the purpose of informing your teaching and enhancing your professionality.

For each resource presented in Tables 1-5, please indicate your frequency of use, and the purpose for which you are using the resource.

For each resource, in each table, please insert X in the appropriate frequency column.

Please briefly describe the purpose for which you use the resource. For example: When ideas are needed on how to teach a new topic.

Please note: We are **only** interested in resources that you use to inform your **teaching of science and developing your professionality**. If you use any of the resources below for personal purposes which are not related to your science teaching, please **do not include it** in your response.

The frequency options are as follows:

1 – Never (0 times in a typical month)

2 – Rarely (1-10 times in a typical month)

3 – Somewhat frequent (11-20 times in a typical month)

4 – Frequently (21-30 times in a typical month)

5 – Very frequently (>30 times in a typical month)

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Table 1. Interactive Media Sources

Source	Frequency of use					The purpose of accessing the resource
	1 Never (0)	2 Rarely (1-10)	3 Somewhat frequent (11-20)	4 Frequently (21-30)	5 Very frequent (>30)	
Twitter						
Facebook						
Skype						
Online courses						
Snapchat						
WhatsApp						
Google docs (and other real time file-sharing platforms)						
Instagram						
Blogs						
Discussion forums (e.g. TES, talkphysics)						
Other (please specify) _____						

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Table 2. Non-Interactive Media Sources

Source	Frequency of use					The purpose of accessing the resource
	1 Never (0)	2 Rarely (1-10)	3 Somewhat frequent (11-20)	4 Frequently (21-30)	5 Very frequent (>30)	
Google (and other search engines)						
Television programs						
YouTube (and other video platforms)						
Online teaching resources banks (e.g. GTAC, TES)						
Online Curriculum						
Other (please specify) _____						

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Table 3. Interpersonal Resources

Source	Frequency of use					The purpose of accessing the resource
	1 Never (0)	2 Rarely (1-10)	3 Somewhat frequent (11-20)	4 Frequently (21-30)	5 Very frequent (>30)	
Conversation with colleagues						
Conversation with friends and family						
Seeking advice of experts						
Other (please specify) _____						

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Table 4. Exhibitory and Experiential Sources

Source	Frequency of use					The purpose of accessing the resource
	1 Never (0)	2 Rarely (1-10)	3 Somewhat frequent (11-20)	4 Frequently (21-30)	5 Very frequent (>30)	
Zoos						
Museums						
Aquaria						
Exhibitions						
Outdoor activities						
Community and social events						
Citizen science						
Public lectures						
Clubs and societies						
Non accredited conferences						
Others (please specify) _____						

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Table 5. Printed Materials

Source	Frequency of use					The purpose of accessing the resource
	1 Never (0)	2 Rarely (1-10)	3 Somewhat frequent (11-20)	4 Frequently (21-30)	5 Very frequent (>30)	
Books						
Newsletters						
Journal articles						
Science magazines						
Other (please specify) _____						

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B. Demographic information

1. How many years have you been teaching secondary science?
   Please circle: >1 2-5 6-10 11-15 16-20 21-30 >31

2. Below is a list of VCE science subjects. Please circle each of the subjects that you have taught at the VCE level.

   Biology Chemistry Physics

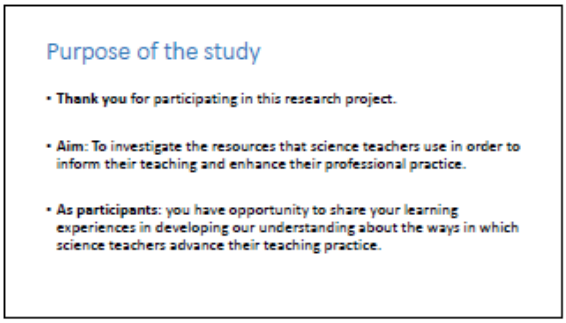
   Other (please specify:_____)

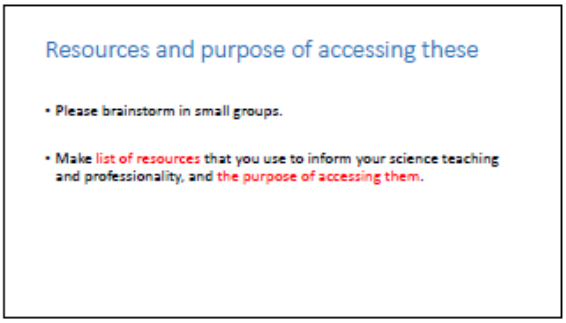
3. Your age category.
   Please circle: 20-30 31-40 41-50 51-60 61-70 >71

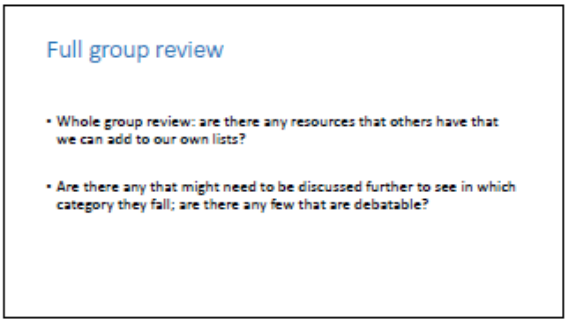
4. **Please circle:** Male Female Other

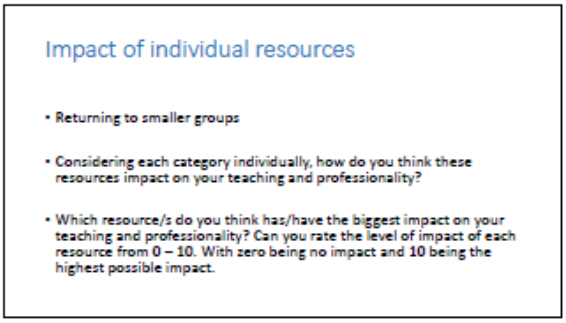
Thank you for taking the time to complete this survey.

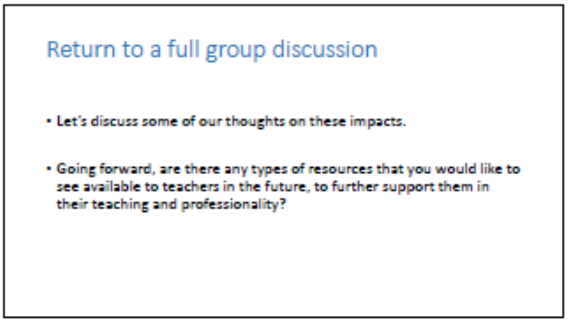
Appendix B. Focus Group Protocol and Focus Group Stimulus Materials











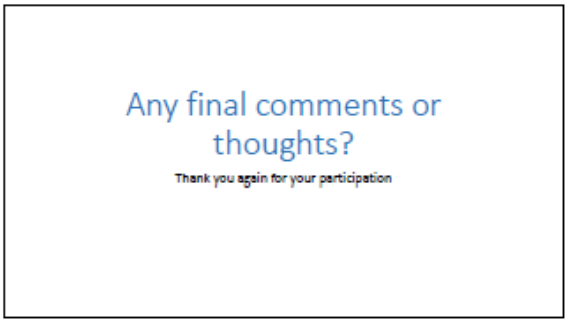


Table 1. Identifying purposes of accessing resources

In the table below, for each type of information source, write how these resources are used and for what purposes.

Types of sources	Uses and purposes of science information resources
Interactive Media Sources	
Non Interactive Media Sources	
Interpersonal Sources	
Exhibitory and experiential sources	
Printed information	

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Table 2. The impact of using science information resources on science teaching and enhancing professionality

Brainstorm all the various impacts that the science information resources have on your teaching and on enhancing your professionality. To the extent possible, try and relate the impacts to the five categories of 'Types of resources'.

Types of sources	The impacts of using science information resources on science teaching and enhancing professionality
Interactive Media Sources	
Non Interactive Media Sources	
Interpersonal Sources	
Exhibitory and experiential sources	
Printed information	

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Table 3. The impact of using science information resources on science teaching and enhancing professionality.

On a scale of 0 – 10. Rate the level of impact on your teaching and professionality, of each type of resource.

Zero (0) - The resource type has no impact,

Ten (10) - The resource type has high level of impact.

Type of resource	Level of impact (0-10)

Appendix C. Calculation and Assumptions in Estimating the Number of Science Teachers in Victoria

To estimate the number of science teachers that were teaching in Victoria in 2017, three sources were used. These sources are presented in Table 1.

Table 1. Data sources used to estimate the number of science teachers in Victoria.

Year of data collection	Title of Report	Organisation
2004	Who's teaching science? Meeting the demand for qualified science teachers in Australian secondary schools	Centre for the Study of Higher Education, University of Melbourne.
2013	Staff in Australia's schools 2013	Australian Council for Educational Research (ACER)
2018	Victorian Teacher Supply and Demand Report	State of Victoria, Department of Education and Training (DET)

The first source used was a study by Harris et al. (2005), who surveyed science teachers across Australia in 2004. They reported responses from 300 of the participants which, they estimated, represented 8.3% of the science teachers in Victoria. If 300 science teachers represents 8.3% of the total, then the total number of science teachers in Victoria is estimated to be 3,615 teachers (p. 5).

The second source used was a study by McKenzie et al. (2014, p. 58). In their study they estimated the percentage of teachers teaching each science in Australia. These results are presented in Table 2.

Table 2. The percentage of secondary school teachers teaching each science in Australia in 2013.

Subject	Percentage of secondary teachers teaching each science in Australia	Estimated total number of teachers in Australia
Biology	3.6	4600
Chemistry	3.4	4300
Physics	3.2	4100
Estimated Total		13000

Adapted from McKenzie et al. (2014, p. 58)

In 2013, Victoria represented 27.1% of secondary teachers in Australia (McKenzie et al., 2014, p. 19). If the total number of secondary school science teachers in

Australia is estimated to be 13,000, then the estimated total number of science teachers in Victoria in 2013 is estimated to be 3,523.

In their report, McKenzie et al. (2014) recognise that these values may be inflated due to double counting of teachers who may teach more than one science subject.

The third source used was the Department of Education and Training (DET) (2020) report on teachers in Victoria. According to this source the total number of secondary teachers in Victoria in 2018 was 36,102. Table 3 applies the percentage of science teachers estimated by McKenzie et al. (2014) to the number of teachers teaching in Victoria in 2018.

Table 3. Calculated number of science teachers for each science subject in 2018.

Subject	Number of secondary teachers in Victoria	Percentage of secondary teachers teaching each science in Australia	Number of teachers teaching each science in Victoria
Biology	36,102	3.6	1300
Chemistry	36,102	3.4	1227
Physics	36,102	3.2	1155
Estimated Total			3682

Finally, the estimated number of science teachers teaching in Victoria that were obtained from each of the three sources is presented in Table 4 for comparison.

Table 4. Comparison of the number of secondary school science teacher in Victoria in 2004, 2013 and 2018.

	Harris, Baldwin, and Jensz (2005)	McKenzie et al. (2014)	DET (2020)
Number of secondary teachers in Victoria			36,102
Biology Teachers			1300
Chemistry Teachers			1227
Physics Teachers			1155
Total Science Teachers in Victoria	3615	3,523	3682

Appendix D. Information to Participants and Participant Consent Forms

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INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled: **Evaluating the role of informal education in secondary school science teachers' professional development.**

This project is being conducted by a student researcher Mr Fiachra Barry as part of a Doctor of Philosophy study at Victoria University under the supervision of Dr Efrat Eilam from the College of Education and Prof. Stephen W. Bigger from the College of Engineering and Science.

Project explanation

The aim of this study is to investigate the role of informal education in secondary school science teachers' professional development (PD).

By understanding the needs of teachers in regard to their informal PD it will become possible to develop more targeted and specific informal education modules.

This study will collect data through written surveys of, and focus group discussions with, secondary school science teachers in Victoria.

What will I be asked to do?

The study will require you to complete:

- focus group discussion, with five other members

What will I gain from participating?

Participants will have an opportunity to share their experiences, and assist in helping better understand the relationship between informal education and secondary school science teachers' professional development.

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How will the information I give be used?

The information which you will be providing will be observed only by the researcher and the thesis supervisors, Dr Efrat Eilam and Prof. Stephen W. Bigger. Your personal information, written or spoken responses, will not be shared with any one in a way that might disclose your identity. All names will be anonymised in any writing that come from the project and findings will be used for educational purposes only.

What are the potential risks of participating in this project?

There are no risks involved.

How will this project be conducted?

The focus group is expected to take approximately 1 hour.

Who is conducting the study?

Chief Investigator: Dr. Efrat Eilam, College of Education, VU Institute of Sustainability and Innovation (ISI) Victoria University, PO Box 14428, Melbourne, VIC 8001 Australia. St. Albans Campus; Room 8. 117. Work: +61 3 99192975 Mobile: +61 40 3282249 Email: Efrat.Eilam@vu.edu.au

Associate Investigator: Prof. Stephen W. Bigger, College of Engineering and Science, Victoria University, Work: +61 3 9919 2959, Email: stephen.bigger@vu.edu.au

Student researcher: Mr Fiachra Barry, Mobile: 0432394661, Email: fiachra.barry@live.vu.edu.au

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

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INFORMATION TO PARTICIPANTS

You are invited to participate

You are invited to participate in a research project entitled: "Evaluating the role of informal learning in secondary school science teachers' professional development."

This project is being conducted by a student researcher, Mr Fiachra Barry, as part of a Doctor of Philosophy study at Victoria University under the supervision of Dr Efrat Eilam from the College of Education and Prof Stephen W. Bigger from the College of Engineering and Science.

Project explanation

The aim of this study is to investigate the sources of information that science teachers use to inform their teaching and professionality.

This study will collect data through written surveys of, and focus group discussions with, secondary school science teachers.

What will I be asked to do?

The study will require you to:

- Complete a written survey.

What will I gain from participating?

Participants will have an opportunity to share their learning experiences, and assist in helping better understand the relationship between informal learning and secondary school science teachers' professional development.

How will the information I give be used?

The information which you will be providing will be observed only by the researcher and the thesis supervisors, Dr Efrat Eilam and Prof Stephen W. Bigger. Your personal information, written or spoken responses, will not be shared with any one in a way that might disclose your identity. All names will be anonymised in any writing that come from the project and findings will be used for educational purposes only.

What are the potential risks of participating in this project?

There are no foreseeable risks involved.

How will this program be conducted?

This is a written survey and is expected to take approximately 20 minutes to complete.

Who is conducting the study?

Supervisors

Dr. Efrat Eilam, College of Education, Victoria University, PO Box 14428, Melbourne, VIC 8001 Australia. St. Albans Campus; Room 8.117. Work: 9919 2975; Email: efrat.eilam@vu.edu.au

Prof Stephen W. Bigger, College of Engineering and Science, Victoria University, Work: 9919 2959; Email: stephen.bigger@vu.edu.au

Student researcher: Mr Fiachra Barry, Mobile: 0432 394 661; Email: fiachra.barry@live.vu.edu.au

Any queries about your participation in this project may be directed to the Supervisors listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001; Email: researchethics@vu.edu.au or phone 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you to be a part of a study into science teacher's use of resources for informing their teaching and professional practice.

This project is part of the requirement for completing a Doctor of Philosophy degree at Victoria University. The aim of this study is to investigate the resources that science teachers use in order to inform their teaching and enhance their professional practice. This study will collect data through written surveys of, and focus group discussions with, secondary school science teachers.

CERTIFICATION BY PARTICIPANT

I, _____

certify that I am at least 18 years old and that I am voluntarily giving my consent to participate in the study: "Science teacher's use of resources for informing their teaching and professional practice" being conducted at Victoria University by Fiachra Barry.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed here under to be carried out in the research, have been fully explained to me by:

Fiachra Barry

and that I freely consent to participation involving the below mentioned procedures:

- Complete a survey

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to student's supervisors Dr. Efrat Eilam, College of Education, Victoria University, PO Box 14428, Melbourne, VIC 8001 Australia. St. Albans Campus; Room 8.117. Work: 9919 2975; Email: efrat.eilam@vu.edu.au or Prof Stephen W. Bigger, College of Engineering and Science, Victoria University, Work: 9919 2959; Email: stephen.bigger@vu.edu.au

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

- If you would like to attend and participate in a focus group discussion about the sources of information that you use to inform your teaching and professionality, please tick the box below and include contact details.

  Please contact me regarding participation in a focus group discussion ☐

  Contact details: _____

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